

Leybourn's Dialling

IMPROV'D;

Or, The Whole ART Perform'd,

I. *Geometrically*: By Scale and Comp'sses, by projecting the *Sphere* upon the *Plain*, whereby the Reasons of the Operations are demonstrated.

II. *Arithmetically*: By Sines and Tangents.

A L S O,

How to describe all necessary Furniture for SUNDIALS, as the Sun's Place and Declination; with the *Babylonish*, *Italic*, and *Jewish* Hours, and the Point of the Compass the Sun is upon at any Time of the Day; and to make Dials to give the Time of the Day at any Place proposed, in any Part of the World.

W I T H

Reflective Dialling: Shewing how to make a Dial that shall give the true Hour of the Day, where the Sun cannot shine.

To which is now added,

Instrumental Dialling: By the Lines of Hours, and Inclination upon the *Scales*, and likewise *Mechanick Dialling*, whereby any Person may, without *Mathematicks*, make a Dial upon any *Plain*; with the Manner of ordering *Oyl* and *Colours* for Painting SUNDIALS.

Concluding with Tables ready calculated for all Latitudes and Declinations, for the more expeditious Drawing the Hour-lines upon any *Plain*.

By HENRY WILSON.

The THIRD EDITION, corrected and improv'd.
By CHARLES LEADBETTER.

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TO THE READER.

MR. *Leybourn's Dialling* being known so universally to be a useful practical Piece, we thought we could not better oblige the World with a Work of that Kind, than by revising and improving what was of principal Use in it, and rendring it useful to all Capacities and Abilities; in order to which,

I. I have corrected the Errors in the Plates, and what was chiefly useful in the Theory and Practice of *Dialling*, in all its Varieties, and upon all Plains.

II. We have added what was wanting to make it compleat; amongst which Additions, are, 1. An expeditious Method to find the Sun's Azimuth: 2. *Instrumental Dialling*, as performed by

the Lines of Hours, and Inclinations, &c. upon the common Scales. 3. *Mechanick Dialling*, shewing how to make a Dial upon any Plain, without Mathematical Instruments, Trigonometrical Tables, or any Knowledge in the *Mathematicks*. 4. The ordering of Oyl and Colours for Painting of Dials; together with several Varieties, as making a Dial to know the Hour of the Day at any Part of the World, &c. These, with other diverting Improvements, are added in this, which were never in any Impression of *Leybourn's Dialling* before.

III. WE have contracted the whole by reducing the Cuts, and engraving them on *Copper-plates*, whereby the Book, (tho' containing all the above-mentioned Additions) will come cheaper than the former Impression.

I know it is a common Objection, that let a Book be never so plain, it is impossible to learn any Science, (whether *Dialling*, or any other) so well by a Book as with a Master. I answer, that may in some Measure be owing to a Want of due Order and Application in reading the Book; as for Instance, Suppose having this Book, and no Instructor;

tor, and it was required to make a *Horizontal Dial* in *Lead, Brass* or *Stone*, turn to Page 37, and there you have such plain Instructions, as if follow'd, you cannot miscarry in your desired Success. Likewise, if it be required to make a *South Dial*, or a *Declining*, or *Reclining*, or *Inclining Dial*, &c. Look in the Table following, it will direct you to the Page, Chapter, and Section, where you have full Directions.

AND because this Book may probably come into the Hands of some *Masons, Carpenters*, or the like, in the Country, that have not attained so much *Mathematicks*, as to qualify them for understanding these Directions, I have, for that Reason, inserted *Mechanick Dialling*, (Chap. 11. Page 215.) whereby any Person that can but read and write, may (by the Directions there given) make any Plain Dial, and perform the whole as well as they that have attained a greater Perfection in the *Mathematicks*.

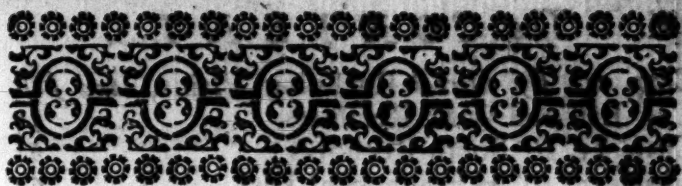
I do not know of any Difficulty the Learner can be under, except in this, that having described the *Hour-lines*, &c. upon his Dial, yet there is not a

Painter present that understands the laying on of Colours in Oyl, so as to endure the Weather, and consequently be fit for painting of Dials.

To prevent, or rather anticipate this Objection also, I have given Directions for the ordering of Oyl and Colours for painting of Sun-dials, (Page 254.) so that this Piece of *Dialling*, with all the above-mentioned Improvements, and others therein contained, and not here mentioned, I think, may, without Presumption, be recommended to the World, as the most perfect Compendium of *Dialling* now extant; and if it be said that Mr. Good's *Dialling* hath acquired the Name of a useful Book, it is easily proved, that it is in Part only a Copy of this, as will appear, by comparing the two last Plates in Good's *Dialling*, with Plate 9 and 10 in this Impression of *Leybourn's Dialling*; and if an imperfect Copy, or Abstract, be of Use, I hope much more the Original, with those useful Additions with which it is now improv'd, by

A true Lover of the Mathematicks,

CHARLES LEADBETTER.



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Geome-



Geometrical Problems.

PROBLEM I.

Upon a Right Line given to erect a Perpendicular

DEFINITION.

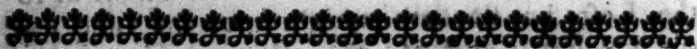


Right Line is said to be perpendicular to another Line, when it maketh the Angles on either Side of the erected Line equal; that is, so that the Line inclines not either to the Right or to the Left, but standeth upright upon the Line upon which it is erected, as in *Plate 1. Fig. 1.* the right Line *A B* is said to be perpendicular to the Line *C D*, upon which it is erected, because the Angles on either Side thereof are equal; namely the Angle *A B C* on the one Side, is equal to the Angle *A B D*, on the other Side, and either of these Angles are called *Right Angles*, and

and the Line A B so erected, is called the *Perpendicular*.

P R A C T I C E.

LET C D be a right Line given, and let it be required to erect a *Perpendicular* thereupon, from the Point B: Open your Compasses to any convenient small Distance, and setting one Foot in the Point B, with the other, make the
Plate 1. other two Marks E and F, on either
Fig. 1. Side of the Point B. ——— This done, open the Compasses to any other convenient Distance greater than the former, and setting one Foot in the Point E, with the other draw the obscure Arch G G, as near as you may guess over the given Point B. Again, (the Compasses being still opened to the same Distance) set one Foot in the Point F, and with the other Foot describe another obscure Arch H H, crossing the former in the Point A, so is A the Point, through which if you draw a right Line from the given Point B, that right Line A B so drawn, shall be perpendicular to the given Line C D, and from the Point B, as was required.



P R O B. II.

How upon (or near) the End of a given right Line, to erect a Perpendicular.

TO effect this, there are several Ways, but I will instance only in two, which are familiar and easy.

The

The First Way.

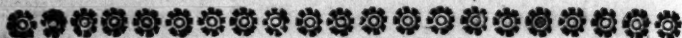
LET A B be a Line given, and from the Point A, which is towards the End thereof, let it be required to erect a Perpendicular A C.

—First open your Compasses to any small Distance, and setting one Foot in the given Point A, with the other describe the Arch F E D; then set one Foot of the Compasses in D, (they being open'd to the same Distance) cross the Arch in E, and setting one Foot in E, with the other describe the Arch A F G crossing the first Arch in F. — Again, set one Foot in F, and with the other describe the small Arch H H, crossing the former in the Point C: So the Line A C being drawn, it shall be perpendicular to the given Line A B, and from the Point A, as was required.

The Second Way.

LET B be the Point given, and from it let it be required to draw the Line B I, perpendicular to A B. — Open the Compasses to any small Distance, and setting one Foot in the given Point B, pitch down the other Foot at all Adventures, as at K, so the one Foot being in K, turn the other Foot about till it cross the given Line A B in L, then through L and K draw the Line L K M, and set the same Distance K L, from K to M, so the Line B I drawn from B, through M, shall be perpendicular to A B, and from the given Point B, as was required.

P. R. O. B.



P R O B. III.

How from a Point above to let fall a Perpendicular to a right Line given.

IN this there are two Cases. First, when the Point above is over (or near) the middle of the Line. And Secondly, when the Point above is near over the End of the Line.

The First Way.

LET R O be a right Line given, and from the Point P, over it, let it be required to
Plate 1. let fall the Perpendicular P Q —
Fig. 3. First, open your Compasses to any Distance greater than P Q, and setting one Foot in the given Point P, with the other describe an Arch of a Circle, cutting the given Line R O, in the Points R S. Then, Secondly, divide the Space between R and S in two equal parts in Q, (by the fourth Problem following) so a Line drawn from the given Point P to Q, shall be perpendicular to the given Line R O.

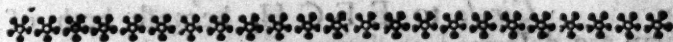
The Second Case.

LET V be the point given, from whence to let fall a Perpendicular to the Line R O, — *First*, from any part of the given Line R O, as from T, draw a right Line to the given point V, which Line (by the next Problem) divide into two equal parts in the point X, with that Extent of the Compasses (one Foot being placed in X) with the other describe the Arch or Semicircle V O T, cutting

Geometrical Problems.

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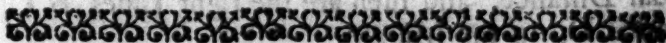
ting the given Line R O in O, a Line drawn from V to O shall be perpendicular to the given Line R O, and towards the End thereof, as was required.



P R O B. IV.

How to divide a right Line given into two equal parts.

LET the Line A B be a Line given, to be divided into two equal parts at right Angles. Take in your Compasses the length of the Line A B, or (if that be too long) any other Distance above half the length thereof, and setting one Foot in the End A, with the other Plate I. draw the Arch C D E, (then the Com- Fig. 4. passess unaltered) set one Foot in B, and with the other Foot cross the former Arch (both above and below the Line) in the points F and G; then a Ruler laid from F to G shall cut the given Line in H, so shall A B be divided into two equal parts in the point H, which was required.



P R O B. V.

A right Line being given how to draw another right Line, which shall be parallel thereunto, at any Distance required, or through any Point assigned.

D E F I N I T I O N.

OF Parallel Lines there are principally two kinds, viz. *Straight or Right Lined Parallels,* and *Circular Parallels.* All Circles that are described or drawn upon the same Center, whether they be

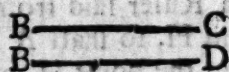
be greater or lesser one than the other, are said to be *Parallel* or *Concentrick Circles*, as

Plate 1. the Circle A B C D may be said to be
Fig. 5. a *Concentrick Circle* with, or a *Parallel*

Circle to E F G H, because both of them are described or drawn upon the same Point or Center O; and of both these Circles, the right Line A C is the Diameter of the greater Circle, and E G of the lesser, the point O is the Center of both, and all right Lines drawn from thence to the *Periphery, Circumference, or Limb* of either of the Circles, are equal, and are sometimes called the *Semidiameters*, and sometimes the *Radius* of the Circle, as the Lines O C or O B of the greater, and O H and O E of the lesser; it containing 60 such Degrees or Parts, of which the whole Circle contains 360.

BUT *Right Lined Parallels*, are such right Lines, that being drawn upon the same Plain, and infinitely extended on either

Side, would never con-
cur or meet, but always
in all parts retain an e-



qual Distance, and such are the right Lines B C, and B D, in the Margin.

IN the describing or drawing of *parallel Lines*, there may fall out two Cases or Varieties: As,

1. It may be required to draw a *Right Line parallel* to another *Right Line*, at a Distance given.
2. It may be required to draw the *Parallel Line* through a Point assigned.

AND of this kind there may be two Cases; For,

1. THE given Point may be over or under the given Line; Or,
2. It may be oblique to the given Line.

PRACTICE.

Of the First Case.

LET EF be a right Line given, and let it be required to draw another right Line parallel thereunto, at the Distance of the Points G and H .

TAKE in your Compasses the given Distance GH , then setting one Foot *Plate 1.* of the Compasses in E , (or any other *Fig. 6.* Point near the End of the given Line) describe a small obscure Arch of a Circle, as IK ; Then moving the Compasses to F , (towards the other End of the given Line,) describe another obscure Arch as LM ; then lay a Ruler to the very Top of these two Arches, so that the Ruler do not cross, but just touch either of them: Then by the side of the Ruler draw the Line NO , and it shall be parallel to the given Line EF , and at the Distance GH , which was required.

The Second Case.

LET PQ be a right Line given, and let it be required to draw another right Line parallel thereunto, which shall pass through the Point R .

FIRST, set one Foot of your Compasses in the given point R , and with the other take the nearest Distance to the given Line PQ , which is done by opening or shutting of the *Plate 1.* Compasses, till the moveable Point do *Fig. 7.* only touch the given Line PQ , describing the Arch st . The Compasses still resting at this Distance, set one Foot in P , (or any other Points to the End of the given Line) and with the other Foot describe the Arch ux . Last-ly,

ly, By the very Top of this Arch Y, draw the right Line Y R, and it shall be parallel to the given Line P Q, and shall pass directly through the given point R, which was required.

The third Case.

LET A B be a right Line given, and let it be required to draw another right Line parallel thereunto, which shall pass through the point C.

TAKE in your Compasses the Distance from the given point C, to the End of the given Line B, then set one Foot in A, the other End of the given Line, and with the other Foot describe the Arch f g. Again, Take in your Compasses the length of the given Line A B, and setting one Foot in C, with the other describe the Arch d e, crossing the former Arch in the Point o, so the Line o C being drawn, shall be parallel to the Line A B, and shall pass through the given Point C, as was required.



P R O B. VI.

Any Three Points (which are not in a straight Line) being given; how to find the Center of a Circle, which shall pass through those three given Points.

LET the three given Points be A B and C, through which it is required a Circle should be described: First, Set one Foot of the Compasses in one of the given Points as in A, and extend the other Foot to B, another of the Points, and draw

draw the Arch of a Circle G E D. Secondly, The Compasses not altered, set one Foot in B, and with the other cross the former Arch with two small Arches, in the Points D and E, and draw the right Line D E. Thirdly, Set one Foot of the Compasses in the third Point C, (they still keeping the same Distance) and with the other Foot cross the first drawn Arch G E D, in the Points B and G, and draw the right Line E G, crossing the former right Line D E, in the point O. So is O the Center sought for; upon which, if you describe a Circle at the Distance O A, it shall pass through all the three given Points A B and C, as was required.

Plate 1.

Fig. 9.



P R O B. VII.

Two Points within a Circle being given, how to find the Center of a Circle, which being described, shall pass through the two given Points; and shall also divide the Periphery or Circumference of the given Circle into two equal Parts.

THIS and the foregoing Proposition, come in continual Use and Practice throughout this Work, and therefore ought more especially to be minded.

LET the Circle given be A B C D, and the two Points within the same be E and F.

FIRST, Through either of the given Points, (as E,) draw a right Line B E D, which must pass through the Center of the given Circle at R.

Secondly

Secondly, draw the Line A C through the Center, and at right Angles to B E D. — Thirdly, from the given Point E draw a right Line E A, and upon the End thereof A, (by the *Fig. 10. second Problem*) erect the Perpendicular A G, crossing the Line B D, (it being extended) in the point G, so shall G be a third Point, and then having the three Points E F and G, (by the last *Problem*) you may find a Center, upon which a Circle being described, shall pass, whose Center will be at H, without the given Circle, upon which point, if you describe the Arch of a Circle at the Extent or Distance of H E, H F, or H G, it shall pass through the two given Points E and F, and divide the given Circle into two equal parts in the points M and L, which was required. And that this Arch thus drawn doth divide the given Circle into two equal Parts, is evident; for a Line drawn from L to M will pass directly through the Center of the given Circle, and shall therefore divide it into two equal parts.



P R O B. VIII.

How to make a Line of Chords Geometrically, to any assigned Length or Radius.

FOASMUCH as through this whole Treatise, there is continual Mention and Use made of a Line of Chords, it will not be impertinent in this place to discover the making thereof, for the Convenience of such, as at all Times, and in all Places, cannot have the Benefit of the *Mathematical Instru-*

Instrument Maker, to whom these Things are common.

DEFINITION.

A Line of Chords is no other than 90 Degrees of the Arch of any Circle, transferred from the Limb of a Circle to a straight Line; now every Circle great or small, is divided (or supposed to be so) into 360 equal parts, called *Degrees*, so the Semicircle contains 180, the Quadrant 90, and the Radius or Semidiameter (which is that Line upon which the Circle or Semicircle is described) noted in the following Figure with the Letters A B, is always equal to 60 Degrees of that Circle which it describes, and therefore 60 Degrees of a *Line of Chords* is called the *Radius* thereof. Thus much for the Definition of a *Line of Chords*; now for

CONCLUSION.

FIRST, Draw a right Line of any length, as F B D, and near the Middle thereof, (by the first or fourth *Problem*) erect the Perpendicular A B.

Secondly, Open your Compasses to the Radius, or length that you would have your *Line of Chords* to be of, which suppose A B, and with that Distance upon B, as a Center, describe the Quadrant R S A D.

Thirdly, Divide the Arch or Quadrant A R S D, into 90 equal parts or Degrees, which you may do in this Manner. (Take the Length of the Line A B, and set that Distance upon the Quadrant

drant A D, from D to R, so is D R 60 deg. and A R 30 deg. Then take the Distance A R, and set it from D to S, so is the Quadrant divided into three equal parts, at the points S and R, each containing 30 deg. This done, divide the several Spaces between A R, R S, and S D, into three equal parts, each of which will be 10 deg. according as you see the Numbers set to them; these must be again divided into two equal parts, each part containing 5 deg. and every of those into five smaller, as you see in the Figure, and so will the whole Quadrant be divided into 90.)

Fourthly, The Quadrant A R S D being thus divided into 90 parts or degrees, set one Foot of your Compasses in D, and open the other Foot to A, and describe the Arch A E F, touching the Line F D in F, so is D F upon the right Line F D, the *Chord* of 90 deg.

Fifthly, Open the Compasses from D to 80 deg. and describe the Arch 80 G H, so shall

Plate 1. H be the *Chord* of 80 deg.

Fig. 11. *Sixthly*, Open the Compasses from D to 70, and describe the Arch 70 I K, so is D K the *Chord* of 70 deg.

AGAIN, Open the Compasses from D to R, the Radius, or 60 deg. and describe the Arch R L B, so is D B the *Chord* of 60 deg. equal to the Radius.

Do the like with 50, 40, 30, 20, and 10 deg. So shall you have the Line D F divided into 90 unequal parts called *Chords*.

IN this Manner may you make a *Line of Chords* of any length; and set it upon a Ruler, and it is fit to perform all the Uses in this Book; and it were convenient that upon one and the same Ruler, you had three, four, or five *Chords* of several

Geometrical Problems.

13

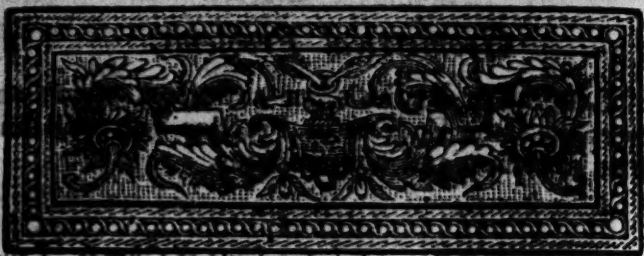
ral Lengths or Radius's, or a Sector, which answers the same End, as in Practice you will find to be necessary and commodious.

Being thus provided of a Line of Chords, I will now shew you how to work two Conclusions Geometrically, which are of absolute Use in Dialling, the one is to find the Hour of the Day, and the other to find the Azimuth of the Sun at any Time, and in any Place. And with them I shall conclude these Geometrical and Astronomical Elements.



B

ASTRO.



ASTRONOMY.

FOR the better understanding of that which followeth, the Reader ought to be acquainted with the principal Circles of the Sphere; as also with such other Lines and Points, as are described and noted upon the Material Sphere or Globe, in Imitation of those which are imagined to be in the Heavens. And of so many of these as are necessary for this our present Purpose, I shall give you a brief Account.

DEFINITIONS.

A *Sphere* or *Globe* is a *solid* Body, containing only one *Superficies*, in whose *Middle* there is a *Point*, from whence all *Right Lines* drawn to this *Superficies* are equal.

THE principal Circles of which a *Sphere* or *Globe* is composed, are in Number ten; whereof six are great and four are smaller Circles.

A *great Circle* is that which divideth the Body of the *Globe* into two equal *Parts* or *Hemispheres*.
A *small Circle* is that which divideth the *Globe* into two unequal *Parts*.

The six great Circles are,

1. The Horizon,
2. The Meridian,
3. The *Æquinoctial*,
4. The *Ecliptick*,
5. The two *Colures*,
6. The two *Colures*.

The lesser Circles are,

1. The *Tropick of Cancer*,
2. The *Tropick of Capricorn*,
3. The *Arctic Circle*,
4. The *Antarctic Circle*.

Of these in the Art of Dialling there are principally but five to be taken Notice of, viz. three great Circles, and two smaller Circles.

The great Circles are,

1. The Horizon,
2. The Meridian,
3. The *Æquinoctial*.

The lesser Circles are,

1. The *Tropick of Cancer*,
2. The *Tropick of Capricorn*.

II. Of the HORIZON.

In the Figure, let the outermost Circle thereof, noted with the Letters H Z O N, represent a Sphere or Globe, then the Horizon is a Circle which divideth or separateth the visible Part of the Heavens which we see, from the invisible

sible Part which we see not, and is represented in the following Figure by the Line (which represents a great Circle) HQO , separating the visible Hemisphere HZO , which we see; from the invisible Part thereof HNO , which we see not.

II. Of the MERIDIAN.

THE Meridian is a great Circle of the Sphere which passeth by the Poles of the World, and through the Zenith and Nadir of Plate 1. the Place. To this Circle when Fig. 12. the Sun cometh, he being above our Horizon, maketh Noon or Mid-day, and being in the same Circle, when it is under the Horizon, it is then Midnight.

THE Zenith is that Point in the Heavens which is directly over your Head, in what Part of the World soever you be. And,

THE Nadir is that Point in the Heavens which is under our Feet, directly opposite to the Zenith.

THE Meridian Circle in this Figure is noted with the Letters HZO , the Point Z at the Top representing the Zenith, and N the Nadir Points.

III. Of the EQUINOCTIAL.

THE Equinoctial is a great Circle of the Sphere, dividing it into the Northern and Southern Hemispheres, which take their Names from the two Poles, that being called the Northern Hemisphere, in which the North Pole is seated, and that the Southern, in which the South Pole is seated.

ed. Unto this Circle, when the Sun in his annual Motion arriveth (which is but twice in the whole Year) the Days and Nights are of equal Length through the whole World.

THIS Circle cutteth the Axis of the World at Right Angles, and is seated in the Heavens 90. Deg. or a Quarter of a Circle, distant from either of the Poles.

It is represented in this Figure by the Line or Circle Æ Q æ . The two Poles are noted with P and S; P being the *North* and S the *South Pole*, and so the Hemisphere æ P Æ , is the *Northern*, and Æ S æ the *Southern Hemisphere*. And the right Line P Q S is the *Axis of the World*, crossing the *Æquinoctial* at Right Angles in Q, the Center, or middle Point of the *Sphere* or *Globe*.

IV. Of the two TROPICKS.

THE two *Tropicks* are smaller Circles of the Sphere, described parallel to the *Æquinoctial* Circle, and at 23 Deg. 29 Min. distant therefrom; that being the greatest Declination that the Sun hath from the *Æquinoctial* towards either of the Poles. Of these Circles one is called the *Tropick of Cancer*, or Northern Tropick; the other the *Tropick of Capricorn*, or Southern Tropick, so denominated from the *Poles* which they respect or behold. As the Tropick of Cancer, marked with the Character of *Cancer*, ☊ ☊ at each End thereof beholdeth P, the *North Pole*, and the Tropick of Capricorn, noted with the Characters of *Capricorn*, ♊ ♊ at each End thereof, respecteth S, the *South Pole*.

THESE two Circles are the Bounds or Limits of the Sun's Course, for between them he always moveth, never going more Northward or South-

ward, (that is, declines not nearer to either of the *Poles*) than 23 Deg. 29 Min. Where-
Plate i. fore, when the Sun in his annual
Fig. 12. Course shall arrive to the Tropick of
Cancer, which is about the 10th of
June, he maketh the *Longest Days* to all that in-
 habit in the Northern Hemisphere. And when
 he arriveth to the Tropick of *Capricorn*, which is
 about the 11th of *December*, he maketh the *Shortest*
Days to those that inhabit the Northern, and the
Longest to those of the Southern Hemisphere.

Besides these Circles here named, there are divers o-
 thers described upon the Globe, two Sorts whereof
 are of great Use in Dialling.

Hour Circles, and Azimuths.

HOUR Circles are great Circles of the Sphere,
 which meet together in the *Poles* of the
 World, and cross the *Æquinoctial* at Right An-
 gles, of which the Meridian (or outward Circle
 in this Figure) is the Hour Circle of 12, the
 streight Line P Q S, which represents the Axis of
 the World, is also the Hour Circle of Six, and all
 the rest of the Hour Circles are drawn from Pole
 to Pole between them, as the Circle P A S, re-
 presents an Hour Circle, and so of all the rest,
 which are 12 in Number, representing the 24
 Hours of the Day and Night being taken round
 the Globe or Sphere.

Azimuths are also great Circles of the Sphere,
 meeting together in the *Zenith* and *Nadir* Points,
 and fall upon, or intersect the *Horizon* at Right
 Angles; as the Hour Circles do the *Æquinoctial*.
 Of these Circles, the outermost Circle of this Fi-
 gure

gure represents the North and South Azimuth ; and the Line ZQN the Azimuth of East and West, and is commonly called the *Prime Vertical Circle*. And all other Circles drawn through the *Zenith* and *Nadir* Points, and cutting the Horizon at Right Angles, are intermediate Azimuths between the East and West, or the North and South Points. As in *Plate 1. Fig. 12.* the Circle ZBN is an intermediate Azimuth between the South and the West.

EVERY Circle of the Sphere hath its proper *Poles*, which are always 90 Deg. distant from it in all Parts.

So in the former Figure Z the *Zenith*, and N the *Nadir* Points, are the *Poles* of the Horizon, they being 90 Deg. distant from O the South Point, from Q the West Point, and from H the North Point of the Horizon.

ALSO Q is the Pole of the Meridian Circle $HZON$, it being 90. Deg. distant therefrom in all Parts.

AGAIN, P and S , the North and South *Poles* of the World, are also the *Poles* of the *Æquinoctial* Circle, they being removed therefrom on either Side 90 Deg.

BUT the *Pole* of the Hour-circle PAS is at C , and the *Pole* of the Azimuth Circle ZBN is at D , and how to find these *Poles*, and also the *Poles* of any Oblique Circles, shall be discover'd in diverse Places of the following Discourse, where there is often Occasion for the finding of them.

Note, And whereas throughout this Book there is continual Mention made of Degrees and Minutes, know that a Degree is the 360th Part of any Circle, each of which Degrees is supposed to be divided into 60 Parts called Minutes, so that 45

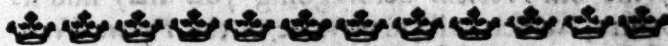
Min. is three Quarters of a Degree, 30 Min. half a Degree, and 15 Min. one Quarter of a Degree, &c.

THESE are such *Astronomical Elements*, as I conceive, most necessary for the understanding that which follows;

It resteth now, that I shew how to perform two or three *Astronomical Conclusions* Geometrically, without which the Knowledge of making of a Dial will be of little Validity; for to what Purpose will a Dial serve without it be rightly placed? Or how can you make a Dial for any appointed Place, without you first know the Position or Situation thereof? And to these Purposes are the following Conclusions subservient.

And because it is requisite to know at all Times of the Year, what Declination the Sun hath from the Equinoctial either Northward or Southward, I have therefore at the End of this Introduction, inserted two Tables, the one shewing the Sun's Declination every Day in the Year. And the other, a Table shewing the Latitudes of all the Principal Cities and Towns in England, Scotland and Ireland.

PROB.



P R O B. IX.

Having the Latitude of the Place, the Altitude of the Sun, and the Day of the Month given, to find the Hour of the Day, and Azimuth of the Sun.

LET the Place be *London*, whose Latitude is 51 Deg. 32 min. North.—Let the Sun's Altitude be 45 Deg.—And let the Day of the Month be the 11th of *May*, at which Time, by the following Table, the Sun's Declination is 20 Deg. 20 Min. North.

FIRST, Describe the Circle *H Z O N*, representing the Meridian of the Place; — Cross it at Right Angles with the two Diameters *H Q O*, for the Horizon, and *Z Q N* for the *Prime Vertical* Circle, or *Azimuth* of East and West.

SECONDLY, Take 51 Deg. 32 Min. the Latitude of the Place, out of your Line of Chords, and set it from *H* to *P* in the North, and from *O* to *S* the South Pole; and draw the Line *P Q S*, for the Axis of the World. And because the *Æquinoctial* Circle is in all Parts distant from the Poles of the World 90 Deg. take 90 Deg. of your Chord, and set them from *P* to *Æ*, and from *S* to *æ*, and draw the Line *Æ Q æ* for the *Æquinoctial* Circle.

THIRDLY, The Sun's Altitude given being 45 Deg. Take 45 Deg. from your Chord, and set them from *H* to *A*, and from *O* to *T*; and lay a Ruler either from *H* to *T*, or from *G* to *A*, and the Ruler will cross the *Prime Vertical* Circle in *L*, through which Point the Circle of the Sun's Altitude must be drawn, and for the drawing of it you have three Points *A L* and *T*, wherefore

B 5

by

by the 6th Problem beforegoing you may find its Centre, which will always be in the *Prime Vertical Circle* Z Q N extended.

FOURTHLY, The Sun's Declination for the Day proposed, (*viz.* the 11th of May) being 20 Deg. 20 Min. Northward, therefore take 20 Deg. 20 Min. out of your Line of Chords, and set them from \mathcal{A} to C, and from \mathfrak{a} to D, towards P the North Pole, because the Declination was North, otherwise it should have been set towards S the South Pole. Then laying a Ruler either from \mathcal{A} to D, or from \mathfrak{a} to C, it will in both Cases cut the Axis of the World in E, through which Point the Parallel of the Sun's Declination for that Day must be described, and for the drawing of it, you have three Points, D E, and C, whose Centre will always be in the Axis of the World S Q P, extended, and may be found by the former 6th Problem.

FIFTHLY, Observe in your Scheme, where the Parallel of Altitude A L T, and the Parallel of Declination D E C, do cross each other, which will be at the Point \odot , and that is the Place of the Sun at the Time of the Question.

SIXTHLY, By the fore-mentioned 6th Problem, draw an Hour-circle through the three Points P \odot and S, whose Centre will always be in the *Æquinoctial Line* extended, if Need be; also thro' the Points Z \odot and N, draw an Azimuth Circle, whose Centre will always be in the *Horizon* extended when Need requires.

THESE two Circles being thus drawn, your Scheme is prepared for the finding both of the Hour and Azimuth in this Manner.



Fig. 1

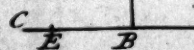


Fig. 5

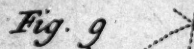


Fig. 9

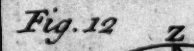
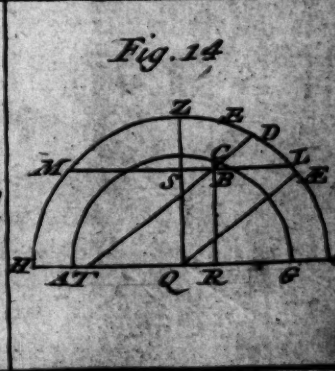
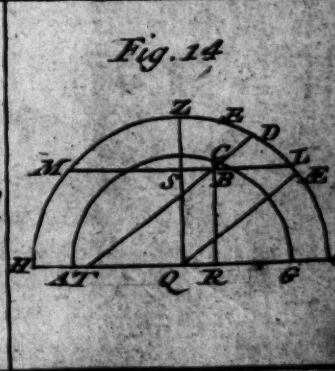
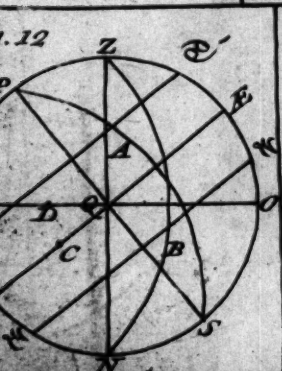
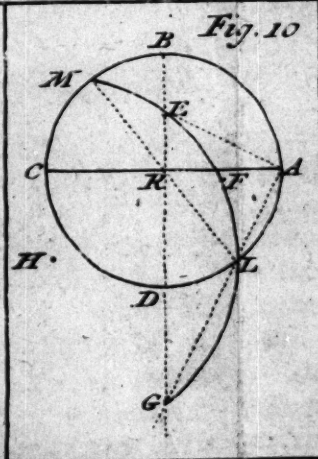
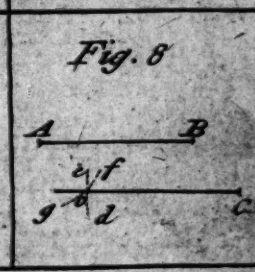
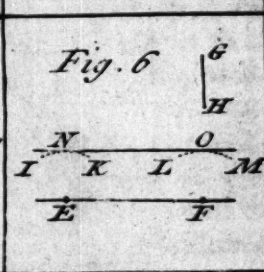
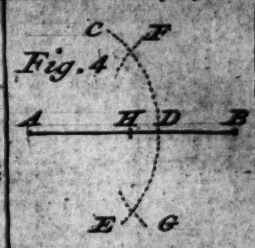
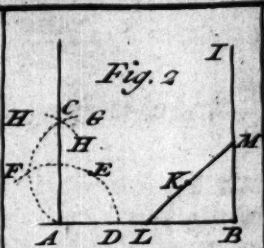


Fig. 12



G
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A

I. For the HOUR.

LAY a Ruler to P, the Pole of the World, and G the Point where the Hour-circle crosseth the Equinoctial; and the Ruler will cut the Circle in *h*. So the Distance from *h* to *E* being measured upon the Line of Chords, will be found to contain 41 deg. 48 min. which is the Hour of the Day, counted from Noon, which reduced into Time (by allowing 15 deg. to an Hour, and 1 deg. to 4 Minutes of Time) will be 2 Hours 47 Minutes, that is, either 47 Minutes after 2 in the Afternoon, or 13 Minutes after 9 in the Forenoon.

II. For the Azimuth.

LAY a Ruler to Z the Zenith, and to B the Point where the Azimuth Circle crosseth the Horizon; and the Ruler will cut the Meridian Circle in the Point *h*. So the Distance *h* Q being measured upon the Line of Chords, will be found to contain 62 deg. 8 min. And such is the Sun's Azimuth from the South Part of the Meridian. Or the Distance N *h* being measured upon the Chords, will be found to contain 27 deg. 51 min. which is the Sun's Distance or Azimuth from either East or West, according to the Time of the Day.

Thus by one and the same Projection of the Sphere, you have found both the Hour and the Azimuth; and many other Conclusions Astronomical might be wrought by this way of Projection, which I have more fully shew'd in my Geometrical Exercises. But seeing that

that the *Azimuth* is of such frequent use in Dialling, that nothing can be done to purpose without it, and that in this Way of Projection, sometimes the Centres of the Circles will be very remote, I will here shew you another Geometrical Way, whereby you may find the *Azimuth* at any Time, and in any Place, by straight Lines, which will be some Light and Ease to the Practitioner, that so he may compare one Way with the other in Case of any Doubt, which will be a good Confirmation of his Work.

Another Way to find the Azimuth.

LET the given Latitude be 51 deg. 32 min.

THE Declination North, 20 deg.

THE Sun's Altitude 40 deg.

AND let the Sun's Azimuth be required.

FIRST, Upon the Centre Q, describe the Semicircle H Z O for half the Meridian, and upon Q, raise the Perpendicular Q Z.

SECONDLY, Set (by the Help of your Line of Chords) 51 deg. 32 min. the Latitude of the Place, from Z to \mathcal{A} , and draw $\mathcal{A} Q$ for the Equinoctial.

THIRDLY, Set 20 deg. the Sun's Declination, from \mathcal{A} towards Z, to the Point D, (being it is North) and draw the Line D T parallel to $\mathcal{A} Q$, so is D B T the Parallel of the Sun's Declination.

FOURTHLY, Set 40 deg. the Sun's Altitude given, from O to L, and from H to M, and draw the Line M S L, for the Parallel of Altitude.

FIFTHLY,

FIFTHLY, Take in your Compasses half the Length of the Parallel of Altitude S L, or S M, and with that Distance upon Q, describe the innermost Semicircle.

SIXTHLY, Through the Point B, which is where the Parallel of Declination, and the Parallel of Altitude do intersect, erect the Perpendicular R C, till it touch the innermost Semicircle at C.

LASTLY, Lay a Ruler from Q to C, and it will cut the outermost Circle in E, so shall H E measured upon the Line of Chords, be 109 deg. 47 min. the Sun's Azimuth from the North Part of the Meridian.

E Z shall be 19 deg. 47 min. the Azimuth from East or West. And,

E O shall be 70 deg. 13 min. the Azimuth from the South Part of the Meridian.

Having made this fair Preparative, I will here insert the two fore-mentioned necessary Tables of the Sun's Declination, and Latitudes of Places; and then proceed to the Art of Dialling, the Thing chiefly intended.

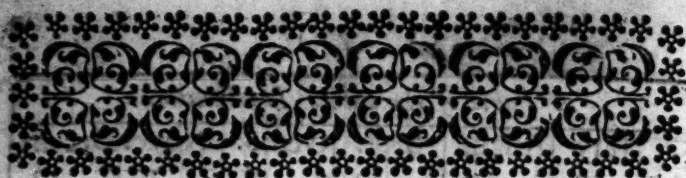


A Table of the Sun's Declinations

Days	January		Febru.		March		April		May		June	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
1	21	44	13	46	3	24	8	35	18	5	23	12
2	21	33	13	26	3	0	8	58	18	20	23	16
3	21	23	13	5	2	37	9	20	18	35	23	19
4	21	13	12	45	2	13	9	42	18	50	23	22
5	21	2	12	25	1	49	10	3	19	4	23	24
6	20	50	12	4	1	25	10	24	19	18	23	26
7	20	38	11	43	1	11	10	45	19	31	23	28
8	20	26	11	21	0	38	11	0	19	44	23	29
9	20	13	11	0	South up to	14	11	27	19	57	23	30
10	20	0	10	38		10	11	47	20	10	23	30
11	19	46	10	16	0	23	12	7	20	22	23	30
12	19	32	9	54	0	57	12	28	20	34	23	30
13	19	18	9	32	1	21	12	48	20	45	23	29
14	19	3	9	10	1	44	13	7	20	56	23	28
15	19	48	8	48	2	8	13	27	21	7	23	27
16	18	32	8	25	2	31	13	46	21	17	23	25
17	18	17	8	3	2	54	14	5	21	27	23	23
18	18	2	7	40	3	18	14	24	21	37	23	20
19	17	45	7	17	3	41	14	42	21	46	23	17
20	17	28	6	54	4	5	15	1	21	55	23	14
21	17	11	6	31	4	28	15	19	22	4	23	10
22	16	54	6	8	4	51	15	37	22	12	23	6
23	16	36	5	45	5	14	15	54	22	20	23	1
24	16	18	5	21	5	37	16	12	22	27	22	55
25	16	0	4	58	6	0	16	29	22	34	22	50
26	15	42	4	34	6	22	16	46	22	41	22	44
27	15	23	4	11	6	45	17	2	22	47	22	37
28	15	4	3	47	7	7	17	18	22	53	22	31
29	14	45			7	30	17	34	22	58	22	23
30	14	26			7	52	17	50	23	3	22	16
31	14	6			8	14		23		8		

A Table of the Sun's Declination.

	July		August		Sept.		Octob.		Nove.		Decem.	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
12	1	22	8	15	12	4	24	7	15	17	40	23
16	2	22	0	14	54	4	2	7	38	17	56	23
19	3	21	5	14	36	3	38	8	0	18	12	23
21	4	21	42	14	17	3	15	8	22	18	28	23
24	5	21	32	13	58	2	52	1	45	18	43	23
26	6	21	22	13	39	2	29	9	7	18	58	23
28	7	21	12	13	20	2	5	9	29	19	13	23
29	8	21	2	13	1	1	42	9	51	19	27	23
30	9	20	5	12	41	1	19	10	13	19	41	22
30	0	20	40	12	21	0	55	10	35	19	55	23
30	1	20	28	12	1	0	32	10	56	20	8	23
30	2	20	16	11	41	0	8	11	18	20	21	23
29	3	20	4	11	21	0	16	11	39	20	34	23
28	4	19	51	11	0	0	39	12	0	20	46	23
27	5	19	38	10	39	1	3	12	21	20	58	23
25	6	19	25	10	18	1	26	12	41	21	9	23
23	7	19	12	9	57	1	50	13	2	21	20	23
20	8	18	58	9	36	2	13	13	22	21	31	23
17	9	18	43	9	15	2	37	13	42	21	41	23
14	10	18	29	8	53	3	0	14	2	21	50	23
10	11	18	14	8	31	3	25	14	21	22	0	23
6	12	17	59	8	9	3	47	14	41	22	9	22
1	13	17	44	7	47	4	10	15	10	22	17	22
55	14	17	28	7	25	4	33	15	19	22	29	22
50	15	17	12	7	3	4	57	15	37	22	33	22
44	16	16	56	6	41	5	20	16	1	22	40	22
37	17	16	39	6	18	5	43	16	19	22	46	22
31	18	16	22	5	56	6	6	16	37	22	52	22
3	19	16	6	5	33	6	29	17	54	22	58	22
6	20	15	48	5	10	6	52	17	11	23	4	21
A	21	15	30	4	47			17	28		21	52



A TABLE of the Names and Latitudes of the Cities, Towns, and Islands in and about Great Britain and Ireland.

<i>England.</i>	D.	M.	<i>England.</i>	D.	M.
B edford	52	8	London	51	32
Berwick	55	50	Northampton	52	14
Bristol	51	27	Norwich	52	41
Buckingham	52	0	Nottingham	53	0
Cambridge	52	12	Oxford	51	46
Canterbury	51	17	Reading	51	28
Carlisle	55	0	Salisbury	51	4
Chichester	50	48	Shrewsbury	52	47
Chester	53	16	Stafford	52	52
Colchester	51	58	Stamford	52	38
Derby	52	58	Truero	50	30
Dorchester	50	4	Warwick	52	20
Durham	54	50	Winchester	51	3
Excester	50	43	Worcester	52	15
Gloucester	51	53	York	53	58
Guilford	51	12			
Hertford	51	49			
Hereford	52	7	<i>Wales.</i>	D.	M.
Huntington	52	19	A nglesey	53	28
Ipswich	52	8	Barmonth	52	50
Kendal	54	23	Brecknock	52	1
Lancaster	54	10	Cardigan	52	12
Leicester	52	40	Carmarthen	51	56
Lincoln	53	14	Carnarvan	53	16

Den-

A TABLE, &c.

29

<i>Wales.</i>	D.	M.	<i>Scotland.</i>	D.	M.
Denbigh	53	13	St. Andrews	56	39
Flint	53	17	Skyraffin	58	36
Landaff	51	35	Stirling.	56	12
Monmouth	51	51			
Montgomery	51	56			
Pembroke	51	46			
Radnor	52	19			
St. Davids.	52	0			

<i>Ireland.</i>	D.	M.	<i>Ireland.</i>	D.	M.
G uernsey	49	30	A Ntrim	54	48
Jersey	49	12	Arglas	54	10
Lundy	51	22	Armagh	54	14
Man	54	24	Caterlagh	52	41
Portland	50	30	Clare	52	34
Wight.	50	39	Corke	51	50
			Droghedagh	53	38
			Dublin	53	20
			Dundalke	53	52
			Galloway	53	2
			Kenny	52	27
			Kildare	53	0
			King's Town	53	8
			Knockfergus	54	57
			Kingsale	51	31
			Lymetick	52	22
			Queen's Town	52	52
			Waterford	52	9
			Wexford	52	13
			Youghall	51	53

<i>Scotland.</i>	D.	M.	<i>Scotland.</i>	D.	M.
A Berdeen	57	32			
Dunblain	56	21			
Dunkel	56	48			
Edinburgh	55	57			
Glasgow	55	53			
Kinsale	57	44			
Orkney	59	56			



The



The ART of
DIALLING

Geometrically perform'd,
By Projecting the Circles of the Sphere
upon the Plain it self.

The First PART.

CHAP. I.

*Of the several Sorts of Plains upon which DIALS
are usually made.*

DI A L S may be made upon any plain
Superficies, and all plain Superficies
are posited in one or other of these
three Positions, viz. either *Parallel*,
Perpendicular, or *Oblique* to the Hori-
zon of the Place wherein the Plain is seated, and
all the Hour-lines drawn upon any Plain, are
great

great Circles of the Sphere, which being projected upon a plain Superficies, become straight Lines.

Now the Art of Dialling consisteth chiefly in the finding out of these Lines, and their true Distances each from the other, which do continually vary, according as the Plains upon which they are described or projected, are situated in respect of the Horizon of the Place.

Of these Plains there are but three Varieties. viz.

1. *Parallel to the Horizon, as is the Horizontal* (which I call *Vertical*) Plain only.

2. *Perpendicular to the Horizon,* and such are all erect Plains. } which be either Direct } North & South } As } East and West } Or Declining.

3. *Reclining from the Zenith, or inclining to the Horizon.* } and these are either Direct } North } Reclining } South } Inclining } East } West } Or Declining } Reclining } Inclining }

Now in the making of particular Dials, which are in Number 25, I reduce them to 17, by supplying the *Inclining Plains* from their opposite *Recliners*, as being indeed the same.

AND to avoid Mistakes, which may possibly arise by comparing my Examples with other Authors, or others with mine: You are to take Notice,

Notice, that I denominate all my *Plains* from the Sight (or the Positions) of their *Axis* in the Heavens, and not from the Circles of the Sphere in which they lie: Therefore take Notice, That Those Plains which most Writers call

Horizontal
Vertical
Meridian
Equinoctial
Polar.

I call
Vertical
North } Direct
South }
East }
West } Direct
Polar
Equinoctial

Because
their
Poles
do lie
in the
North } Points of the
South } Horizon.
East } Points of the
West } Horizon.
Poles of the World.
Equinoctial Circle.

AGAIN,

the
Hea-
in

Again, all leaning Plains, whether Direct or Declining, whose upper Faces behold the Zenith, I call *Recliners*; and the nether, or under Faces of them, which respect, or look down to the Nadir, I call *Incliners*.

This Distinction being made, the Plains of all which Examples following, are thus denominated.

1. *Vertical* or *Horizontal*.
2. *South* and *North* Direct.
3. *East* and *West* Direct.
4. *South* and *North*, declining $\left\{ \begin{array}{l} \text{East} \\ \text{Or,} \\ \text{West.} \end{array} \right.$
5. *East* and *West* Direct. $\left\{ \begin{array}{l} \text{Reclining} \\ \text{Or,} \\ \text{Inclining.} \end{array} \right.$
6. *Equinoctial*, Or, *South* Reclining or Inclining to the *Pole*.
7. $\left\{ \begin{array}{l} \text{South Direct Recli-} \\ \text{ning or Inclining} \end{array} \right\} \left\{ \begin{array}{l} \text{less} \\ \text{more} \end{array} \right\} \text{than the Pole.}$
8. $\left\{ \begin{array}{l} \text{South Direct Recli-} \\ \text{ning or Inclining} \end{array} \right\} \left\{ \begin{array}{l} \text{less} \\ \text{more} \end{array} \right\} \text{than the Pole.}$
9. *Polar*, Or *North* Reclining or Inclining to the *Equinoctial*.
10. $\left\{ \begin{array}{l} \text{North Direct Recli-} \\ \text{ning or Inclining} \end{array} \right\} \left\{ \begin{array}{l} \text{less} \\ \text{more} \end{array} \right\} \text{than the Equinoctial.}$
11. $\left\{ \begin{array}{l} \text{North Direct Recli-} \\ \text{ning or Inclining} \end{array} \right\} \left\{ \begin{array}{l} \text{less} \\ \text{more} \end{array} \right\} \text{than the Equinoctial.}$
12. *Equinoctial*, Or *South* Declining *East* or *West* Reclining to the *Pole*.
13. $\left\{ \begin{array}{l} \text{South declining East} \\ \text{or West Reclining} \end{array} \right\} \left\{ \begin{array}{l} \text{above} \\ \text{under} \end{array} \right\} \text{the Pole.}$
14. $\left\{ \begin{array}{l} \text{South declining East} \\ \text{or West Reclining} \end{array} \right\} \left\{ \begin{array}{l} \text{above} \\ \text{under} \end{array} \right\} \text{the Pole.}$
15. *Polar* or *North* declining *East* or *West*, Reclining or Inclining to the *Equator*.
16. $\left\{ \begin{array}{l} \text{North declining East} \\ \text{or West Reclining} \end{array} \right\} \left\{ \begin{array}{l} \text{above} \\ \text{under} \end{array} \right\} \left\{ \begin{array}{l} \text{the Interse-} \\ \text{ction of the} \\ \text{Meridian \&} \\ \text{Equator.} \end{array} \right.$
17. $\left\{ \begin{array}{l} \text{North declining East} \\ \text{or West Reclining} \end{array} \right\} \left\{ \begin{array}{l} \text{above} \\ \text{under} \end{array} \right\} \left\{ \begin{array}{l} \text{the Interse-} \\ \text{ction of the} \\ \text{Meridian \&} \\ \text{Equator.} \end{array} \right.$

Thus

THUS are the several Plains denominated, I shall now shew how the Situation of any Plain may be attained, either in respect of its Declination or Reclination.

CHAP. II.

How to find the Reclination and Declination of any Plain.

I. For the Reclination.

THE *Reclination* of a Plain, is the Arch of the Vertical Circle or Azimuth, which is perpendicular to the Reclining Plain, or that Azimuth, in which the *Pole* of the Reclining Plain lieth, comprehended between the Zenith of the Place, and the Reclining Plain.

To find which, let A B C D be a *Reclining Plain*, draw first thereon by the Help of a Ruler and Quadrant, a Line G H parallel to the *Horizon* of the Place, which shall be the *Horizontal Line* of the Plain, and cross at it right Angles with another right Line K S, for the *Vertical Line* of the Plain; to this *Vertical Line* K S, apply a straight Ruler K I, and to that End of it which lieth clear of the Plain as I, apply a Quadrant as O L I; having a Thread or Plummet hanging from the Centre at I, then see what Number of Degrees of the Quadrant are contained between O and L, for so much doth the Plain recline from the Zenith.

II. For

H. For the Declination.

THE Declination of a *Plain*, is an Arch of the Horizon comprehended between the *Pole* of the *Plain*, and the *Meridian* of the *Place*. Or it is the Distance of the *Plain* itself, from the prime Vertical Circle, or Azimuth of *East* and *West*.

To find out the Declination of any *Plain*, there are required two Observations to be made by the Sun at the same Instant of Time. The first of the Horizontal Distance of the Sun from the *Pole* of the *Plain*. And secondly, Of the Sun's Altitude.

1. To find the Sun's *Horizontal Distance* from the *Pole* of the *Plain*. Apply one Edge of a Quadrant to the Horizontal Line of your *Plain*. so that the other may be perpendicular to it, and the Limb of the Quadrant may be towards the Sun, and hold the whole Quadrant Horizontal (as near as you can conjecture.) Then holding up a Thread and Plummer at full Liberty, so that the Shadow of the Thread may pass both through the Center and Limb of the Quadrant, observe then the Degrees cut by the Shadow of the Thread, and number them from that Side of the Quadrant that standeth square or perpendicular to the *Plain*. For those Degrees are the Horizontal Distance required.

2. This Horizontal Distance and the Sun's Altitude being observed at the same Time, (as near as may be) will help you to the *Plain's* Declination by the Rules following.

FIRST, By having the Altitude, you may find the Azimuth by the two last *Problems* of the Introduction, then by comparing the Azimuth and

and this Distance together, you may find the *Plain's Declination* in this Manner.

WHEN you make your Observations of the Sun's *Horizontal Distance*, mark whether the Shadow of the Thread fall between the *South*, and that Side of the Quadrant which is perpendicular to the *Plain*.

1. IF the Shadow fall between them, the *Azimuth* and *Distance* added together, do make the *Declination* of the *Plain*, and in this Case the *Declination* is upon the same Coast whereon the Sun's *Azimuth* is.

2. IF the Shadow fall not between them, then the Difference between the *Distance* and *Azimuth* is the *Plain's Declination*; and if the *Azimuth* be the greater of the two, then the *Plain* declines to the same Coast whereon the Sun is; but if the *Distance* be the greater, then the *Plain* declines to the contrary Coast.

AND here note, that the *Declination* thus found is always accounted from the *South*, and that all *Declinations* are counted from either *South* or *North*, towards either *East* or *West*, and must never exceed 90 Degrees,

1. IF therefore the Degrees of *Declination* from the *South* do exceed 90, you must take the Residue of that Number to 180, and that shall be the *Plain's Declination* from the *North*.

2. IF the Degrees of *Declination* exceed 180, then the Excess above 180 Degrees gives the *Plain's Declination* from the *North* towards that Coast, which is contrary to the Coast whereon the Sun is.

I. Of Vertical Dialling.

C H A P. III.

How to draw the Hour-Lines upon a Vertical (commonly called Horizontal) Plain.

Example, Of a Vertical or Horizontal Plain in the Latitude of London, which is 51 deg. 32 min.

FIRST, Draw a Circle E S W N, which Circle let represent your Vertical Plain; cross it in the Middle thereof at right Angles with the two Diameters, viz. S Q N, for the Meridian; and Hour-line of 12, and E Q W for the prime Vertical or Hour-line of 6.

SECONDLY, Because the Latitude of the Place is 51 deg. 32 min. take 51 deg. 32 min. out of your Line of Chords, and set that Distance from S to *a*, and from W to *b*.

THIRDLY, Lay a Ruler from E to *a*, and it will cut the Meridian Line S N, in the Point P, which Point P is the Pole of the World: And a Ruler laid from E to *b*, will cut the Meridian in the Point *Æ*, so is *Æ* the Point where the Equinoctial crosseth the Meridian; and thus have you three Points, viz. E, *Æ*, and W, through which you must draw the Equinoctial Circle E *Æ* W, whose Center will always be in the Meridian S N. So that you may easily find it, as hath been before taught, and in this Manner also. Draw the Line *Æ* W, which divide in

A Vertical or Horizontal Dial for the Latitude of London, 51 deg. 32 min. Plate 2. Fig. 2.

two equal Parts in the Point A, upon which Point A, raise the Perpendicular A C, cutting the Meridian S N, in the Point C, which is the Center of the Equinoctial Circle E \mathcal{A} W, upon which Point, and the Distance C \mathcal{A} , you may describe it.

FOURTHLY, Divide the Semicircle E N W, into 12 equal Parts at the Points $\odot \odot \odot$, &c. beginning at the Point N, and setting 6 on either side thereof. The Semicircle may easily be divided into 12 Parts in this Manner; for 60 deg. of the Line of Chords will divide it into three equal Parts, and 30 deg. will divide each of them into two, that is, into 6 equal Parts, and 15 deg. is the half thereof, which is a twelfth Part of the Semicircle.

FIFTHLY, Lay a Ruler to Q, the Center of the Plain, and upon every of these Points $\odot \odot \odot$, and the Ruler will cut the Equinoctial E \mathcal{A} W, in the Points * * * &c. dividing that into 12 unequal Parts.

SIXTHLY, A Ruler laid to P, the Pole of the World, and the several Points * * *, &c. upon the Equinoctial, will cut the Circle representing the Plain in the Points |||, &c. dividing the Semicircle E N W, in 12 other unequal Parts.

LASTLY, From the Point Q, and through the several Points |||, &c. draw straight Lines, as Q 17, Q 18, Q 19, &c. they shall all be the true Hour-lines for such a Vertical or Horizontal Plain. Namely, for twelve of them, that is, from 6 in the Morning till 6 at Night.

BUT for the Hours before and after 6, that is, for 4 and 5 in the Morning, and for 7 and 8 at Night, they are to be drawn by extending the Hour-line of 7 and 8 in the Morning through the Center Q, and drawing them on the other side of the

the *Plain*, so shall they be the Hours of 7 and 8 at Night: — Also the Hour-lines of 4 and 5 in the Evening, being drawn through the Center Q, will become the Hour-lines of 4 and 5 in the Morning.

For the *Stile* of this *Dial*, take 51 deg. 32 min. the Latitude of your Place, out of your Line of Chords, and set them from N to e, upon the Circle of the *Plain*, so shall a Line drawn from Q through e, be the *Axis* or *Stile* of the *Dial*, which may be a thin Plate of Brass, cut exactly to the Quantity of the Angle e Q N. 51 deg. 32 min. and set perpendicularly upon the Line of 12, or the Meridian S Q N, with the angular point at Q, and thus is your *Dial* finished.

If into this, or any of the following *Dials* you have a Desire to insert the half Hours and Quarters, divide the Spaces between every one of the Points ☉ ☉ into two equal Parts for the Half, and into 4 equal Parts for the Quarters of Hours, and proceed with putting on of them in all Respects as you did with the whole Hours.



II. Of Upright or Erect Plains.

C H A P. IV.

THOSE Plains are said to be *Erect* or *Upright*, which stand perpendicular to the *Horizon* of the *Place*, whose Vertex or upper Part tendeth to the *Zenith*, and their lower Part to the *Nadir*, and such are the Walls of Steeples, Churches,

Churches, Houses, or the like, against which (for the most part) *Dials* are made.

OF these *Upright* or *Erect Plains* there are two Sorts, viz. *Direct* and *Declining*.

THOSE *Erect* or *Upright Plains* are said to be direct, which do directly behold either the true East, West, North or South Points of the *Horizon*, or whose *Poles* do lie direct in either of them, and these *Plains* are called *Erect Direct Plains*.

THOSE *Erect* or *Upright Plains* are said to decline, which do not lie in, or directly behold any of these Points, but are situate under some other *Azimuth*, as *South-East*, *North-West*, *North-East*, &c. and these *Plains* are called *Erect* or *Upright Declining Plains*. Of both which sorts I shall give you Examples. And,

I. Of *Upright*, or *Erect Direct Plains*.

C H A P. V.

How to draw the Hour-lines upon a Direct South Plain.

Example, Of a Direct South Plain, in the Latitude of London, 51 deg. 32 min.

FIRST, Draw a Circle *Z E W N*, representing an upright direct South Plain, cross it at right Angles with the Diameter *Z Q N* for the Meridian, or Hour-line of 12, and *W Q E* for the prime *Vertical Circle*, or Hour-line of Six.

SECONDLY, Out of your Line of Chords take 38 deg. 28 min. (which is the Complement of the

the *Latitude* of the *Place*) and set that Distance upon the *Dial-plain* from *Z* to *a*, and from *E* to *b*, and from *N* to *c*.

THIRDLY, Lay a Ruler from *W* to *a*, it will cut the Meridian *Z N*, in the Point *P*, the *Pole* of the *World*; and a Ruler also laid from *W* to *b*, will cut the Meridian in *Æ*, so is *Æ* the Point through which the *Equinoctial* must pass; and for the drawing of it you have three Points given, viz. *E*, *Æ*, and *W*, and the Center will always be in the Meridian Line *Z N*, (extended, if need be.) The Center you may find by the Geometrical Way taught at the Beginning of the Book. Or thus, draw the Line *E Æ*, and divide it into two equal Parts in *A*, upon *A* erect the *Perpendicular* *A C*, *An Erect Direct* extending it, till that and the *South Plain. Pl.* Meridian Line concur in *G*, 2. *Fig. 3.* so is *G* the Center of the *Equinoctial Circle E Æ W*.

FOURTHLY, Divide the Semicircle *E N W* into 12 equal Parts, at the Points $\odot \odot \odot$, &c.

FIFTHLY, Lay a Ruler to *Q*, and each of these Points $\odot \odot \odot$, and the Ruler will cross the *Equinoctial Circle* in the Points * * *, &c. dividing that into 12 unequal Parts.

SIXTHLY, Lay a Ruler to *P*, (the *Pole* of the *World*) and every of the Marks * * *, &c. and the Ruler will cross the Circle of the *Plain* in the Points $\parallel \parallel$, &c.

LASTLY, If through the Center *Q*, and the respective Points $\parallel \parallel$, &c. you draw right Lines, they shall be the true Hour-lines of an *Erect Direct South Plain*.

FOR the *Stile*, take 38 deg. 28 min. the Complement of the *Latitude* of your *Place*, out of the Line of Chords, and set them from *N* to *e*,

drawing the Line *Qe* for the Axis of the Stile, which must hang directly over the Meridian, or Hour-line of 12, and must point downwards towards the South Pole, because the Plain beholds the South Part of the Meridian.

IN making this Dial you have made two Dials, for the *Erect Direct North Dial* is but the back-side of the *South*, it lying in the same prime Vertical Circle, only as this beholdeth the South Part of the Meridian, and hath the South Pole elevated above it, the other beholdeth the North Part of the Meridian, and hath the North Pole elevated above it, and as the Meridian Line *ZQ* *N* in the *South Dial* representeth the 12 a Clock Hour-line at Noon, the back-side thereof (namely the North-side) representeth the Hour-line of 12 at Midnight, and therefore is not expressed, neither the Hour lines of 9, 10, 11 at Night, or of 1, 2, 3 in the Morning, the Sun to us never being above the Horizon at those Hours: Wherefore the North Dial is only capable of receiving these Hours, namely, 4, 5, 6, 7 and 8 in the Morning, and of 4, 5, 6, 7 and 8 at Night, and (in this Latitude) not of all them neither; for it will never shine upon this Plain at

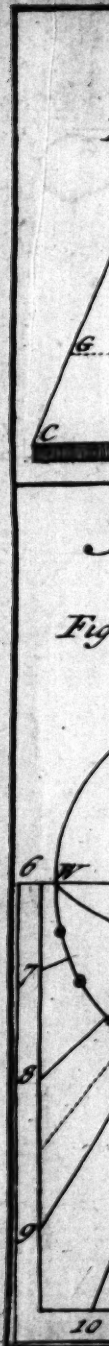
An Erect Direct North Plain. Plate 8 in the Morning, or at 4 in the Afternoon, but it is best to put them on (as in the Figure) that thereby you may know how much it is past 7 in the Morning, and how much it wants of 5 in the Afternoon.

Fig. 4.

CHAP.

Of the Dial of the North Pole.

Fig. 5.



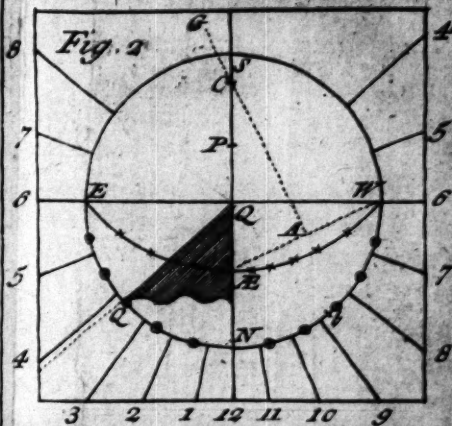


Fig: 3

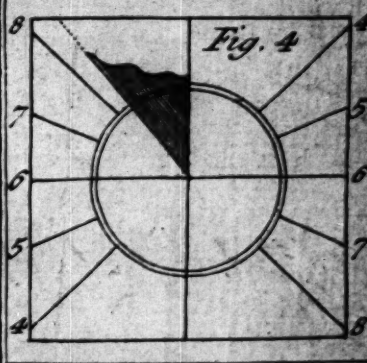
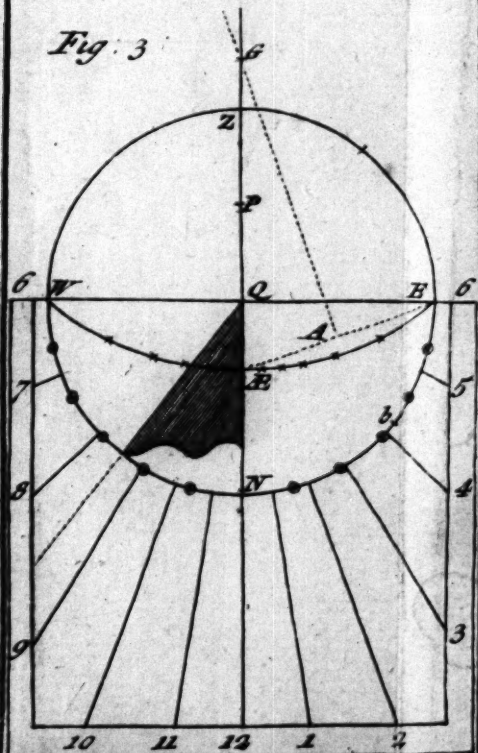


Fig. 5

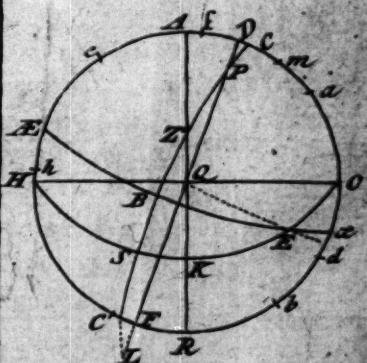




Plate 2



C H A P. VI.

How to draw the Hour-lines upon an Erect, Direct, East, or West Plain.

I Call that an *East* or *West Plain*, which lies in the Meridian of the Place, and whose Poles lie in the Prime Vertical Circle, or *Azimuth* of East or West.

Now for as much as the Plain lieth in the very Meridian Circle, in which also the two Poles of the World are seated, the Plain must necessarily pass through both these Poles, and so neither of them can have any Elevation above it; wherefore the Hour-lines in these *Dials* must be parallel to one another, and consequently parallel to the Axis of the World. And the Dial must have no Center: However the Dial may be drawn as followeth.

Example. Of an East Direct Dial, in the Latitude of London 51 deg. 32 min.

LET A B C D be a Dial-plain, upon which you would draw a direct *East Dial*, upon the Point D, if it be an East Dial; or upon the Point C, if it be a West Dial, with the Radius (or 60 deg.)

of your Line of Chords, describe an obscure Arch of a Circle E F, then from your Chord

take 38 deg. 28 min. the Complement of the Latitude of the Place, (which is also the Height or Elevation of the Equinoctial) and set them from E to F, and draw the Line D F quite through the Plain. Then, that you may proportion your

Stile to your Plain, so that you may bring on all the Hours from Sun-rising to 11 a Clock, assume two Points in the Line F D, one towards the End D (at the Point G) for the Hour-line of 11, and another at H, for the Hour-line of 6, and through the Points G and H, draw the Lines 11 G 11, and 6 H 6, perpendicular to the Equinoctial Line D F. This done, upon the Point G, with 60 deg. of the Line of Chords, describe an obscure Arch of a Circle I K, and set thereon 15 deg. of your Line of Chords from I to K, and draw the Line G K, to cut the Line 6 H 6 in the Point L, so shall L H be the Height of the perpendicular Stile proportioned to this Plain.

Now for the drawing of the Hour-lines, set one Foot of the Compasses, (opened to 60 deg. of the Chord) in L, and with the other describe the Arch of a Circle M N, betwixt the Hour-line of 6, and the Line G L, which divide into 5 equal Parts in the Points $\odot \odot \odot \odot \odot$, and a Ruler laid from the Point L to each of these Points, $\odot \odot \odot$, &c. will cut the Equinoctial Line H D, in the Points * * * *, through which Points draw Lines parallel to 6 H 6, as the Lines 7 * 7, 8 * 8, &c. and they shall be the true Hour-lines of an *East Plain*, from 6 in the Morning till 11 before Noon, but for the Hours of 4 and 5 in the Morning, you may put them on by setting the same Distances upon the Equinoctial Line before 6, as there is from 6 to 7 and 8, after 6; and through those Points draw the Hour-line of 4 and 5, parallel to the Hour of 6, as you see done in the Figure.

THUS is your *Dial* finished, and in the making of it you have made two *Dials*, namely, a *West Dial* as well as an *East*, for it is the same in all Respects.

spects. Only whereas the Arch A F through which the Equinoctial passeth in the East Dial, was drawn on the Right-hand of the Plain, in the West it must be drawn on the Left-hand, and the Hour-lines of 4, 5, 6, 7, 8, 9, 10, and 11, in the Forenoon on the East Dial, must be 8, 7, 6, 5,

An Erect, Direct West Dial. Plate 3. Fig. 2.

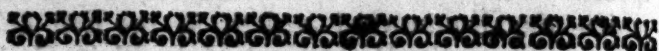
4, 3, 2, and 1 in the Afternoon upon the West Dial.

THE Stile of the East or West Dials may be either a strait Pin of the just Length of the Line H O, which is equal to H L in the East Dial, fixed in the Point H, upon the Hour-line of 6, and exactly perpendicular to the Plain, shewing the Hours of the Shadow of the Apex, or very Top thereof.

OR, it may be a Plate of Brass of the same Breadth with the Distance between the Hour-lines of 6 and 3, which Plate must be set perpendicular upon the Hour-line of 6, and so it will shew the Hour by the Shadow of the upper Edge thereof, as in this West Dial.

THESE five Dials here described, viz. the *Vertical*, the *South*, *North*, *East*, and *West Erect, Direct*, may be made upon a Stone cut square in form of a *Die*, which Body is called a Cube.





II. Of Upright Declining Plains.

C H A P. VII.

How to draw the Hour-lines upon a South or North Erect Plain, Declining either East or West.

THE upright or erect Plains, that we have hitherto treated of, are such as did directly behold the four Cardinal or principal Points of the Horizon, namely, the *East, West, North* and *South* Points. All other upright Plains are said to decline, and their Declination is counted from the North or South, towards East or West, and these Plains are called South or North Erect Plains declining East or West.

BEFORE the Hour-lines can be drawn upon any of these Plains, two Things must be given, and three other Things must be found. —

The Things given must be,

1. The Latitude of the Place.
2. The Declination of the Plain.

The Things required are,

1. The Height of the *Pole* (or *Stile*) above the Plain.
2. The Distance of the *Substile* from the Meridian, or 12 a Clock Hour-line.
3. The *Plain's* Difference of Longitude.

FOR the finding of these, we must project upon the *Plain* such Circles of the Sphere (in their true Posi-

Positions) as are requisite for the finding of them, and those Circles are, the *Horizon*, the *Meridian*, and the *Equinoctial*: Which I shall shew how to perform by giving an

Example of a South Erect Plain, declining Westward 24. deg. 20 min. in the Latitude of London 51 deg. 32 min.

		d.	m.
Given {	Latitude of the Place	51	32
	Declination <i>South West</i>	24	20

		d.	m.
Required {	Distance of the Substile from the Meridian,	18	8
	Height of the Pole (or Stile) above the Plain,	34	33
	Plain's Difference of Longit.	30	00

To find which,

First, Describe the Circle *Z H N O*, representing the declining Plain, cross it at right Angles, with the two Diameters *Z Q N*, and *H Q O*, the Point *Z* representing the Zenith, and *N* the Nadir, and the Line *Z Q N*, the vertical or perpendicular Line of the Plain (and the Hour-line of 12) and the Line *H Q O* is the Horizontal Line thereof.

Secondly, Because the Plain declines 24 deg. 20 min. from the South Westward, set 24 deg. 20 min. from *N* to *a*, and from *O* to *c*. Then lay a Ruler from *Z* to *a*, and it will cut the Horizontal Line *H Q O* in *S*, so is *S* the South Point of the Horizon, through which the Meridian must be drawn, and for the drawing of it you have three Points, viz. *Z S* and *N*, and the Center

C 6.

will

An Upright Plain will always be in the
Declining from the South Horizontal Line HQ
Westward 24 d. 20 m. O , extended if need be.
Plate 3. Fig. 3. Which Center may be

found *Geometrically*, as is
 formerly taught. Then lay a Ruler from Z to c ,
 and it will cut the Horizon in W , the West Point
 thereof.

Thirdly, Having drawn the Meridian and the
 Horizon, take $51^{\circ} 32'$ out of your Line
 of Chords, and set them upon your Plain, from
 H to b , and from N to d .

Fourthly, Lay a Ruler upon W , the West Point
 of the Horizon, (which is also the Pole of the
 Meridian) to b , and it will cut the Meridian in
 the Point P , so shall P be the Pole of the World,
 through which Point P , and Q (the Pole of the
 Plain) draw the strait Line $BPQD$, representing
 the Axis of the World, and the Substilar Line of
 the Dial.

Fifthly, Lay a Ruler from W to d , and it will
 cross the Meridian in the Point $\mathcal{A}E$, so is $\mathcal{A}E$ one
 Point in the Meridian, through which the Equi-
 noctial must pass: And the Point W in the Hori-
 zon is another. So have you two Points within
 the Circle, by which to draw the Equinoctial,
 which you may do *Geometrically*, as is before
 taught. Or you may find it thus, the Center of
 the Equinoctial will always be in the Axis of the
 World, and therefore in the Line $BPQD$. Now
 to find the Point, draw the Line $\mathcal{A}EW$, which
 divide into two equal Parts in the Point n , upon n
 erect a Perpendicular, till it cut the Axis of the
 World, extended in m . So is m the Center of
 the Equinoctial, upon which Point you may de-
 scribe it. And thus have you drawn upon your
 Plain all the three Circles required, viz. the
 Horizon,

Horizon, Meridian, and the Equinoctial; by which may be found the three Requisites belonging to this Plain. For,

1. *To find the Height of the Pole above the Plain, represented in the Scheme by the Line P B.* Lay a Ruler to G, where the *Equinoctial* cuts the Plain, and to P the Pole of the World, the Ruler will cut the Plain on the opposite Side in the Point *v*. So the Distance from B to *v*, measured upon the Line of Chords, will be found to contain 34 deg. 33 min. the Height of the Pole above the Plain.
2. *To find the Distance of the Substile from the Meridian, represented in the Scheme by the Arches Z B, or N D.* Take in your Compasses the Distance Z B, or N D, and you shall find either of them equal to 18 deg. 8 min. and such is the Distance of the Substile from the Meridian.
3. *To find the Plain's Difference of Longitude, represented in the Scheme by the Angle Æ P K.* Lay a Ruler from P to Æ, it will cut the Plain in *x*, so the Distance between D and *x*, measured upon the Line of Chords, will be 30 deg. And such is the Plain's Difference of Longitude.

Lastly, These Requisites being obtain'd, we come to the drawing of the Hours; to effect which, lay a Ruler to P, the Pole of the World, and Æ, the Intersection of the *Equinoctial* with the *Meridian*, and it will cut the Plain in the Point *x*. — At this Point *x* begin to divide the Semicircle L *x* G, into 12 equal Parts, at the Points ☉ ☉ ☉, &c. Then laying a Ruler to Q, and every of these Points ☉ ☉ ☉, &c. it will cut the *Equinoctial* Circle, dividing that into

12 equal Parts in the Points * * * *, &c. —
 Again, A Ruler laid to P, and every of these unequal Parts * * * *, &c. will divide the Plain into 12 unequal Parts in the Points 1 1 1 1, &c. —
 Lay a Ruler to Q, and every of these Points 1 1 1, &c. drawing Lines by the Side thereof and they shall be the true Hour-lines proper to such a declining Plain.

Thus have you finished the Hour-lines, the Substilar-line, (or the Line upon which the Stile must stand) is the Line Q D, falling (in this Dial) just upon the Hour-line of 2 in the Afternoon, because the Plain declined Westward. The Angle of the Stile is D Q R, containing 34 deg. 33 min. and must be either of Plate or Wire brought to such an Angle, and must stand perpendicular to the Plain, and directly over the Substilar Q D.

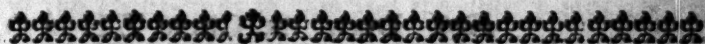
Now have you finished your Dial, and in so doing you have in this one made four Dials, viz..

A	{	South declining West	{	d.	m.
		South declining East			
		North declining West			
		North declining East			
				24	20

ONLY placing of the Numbers of the Hours and the Stile respectively upon each Plain. For in the South-west Plain, which we have now described, the Stile stands upon the Hour-line of 2 in the Afternoon; in the South-East declining as much, it will stand upon the Hour-line of 10 before Noon. And so all the Morning Hours of the West Decliner, will be the Afternoon Hours of the East Decliner; and the Afternoon Hours of the West Decliner, will be the Morning Hours of the East Decliner: And so the South Decliner will

will produce the North-west Decliner; and the South-west Decliner, the North-east Decliner, by only extending the *Hour-lines, Stile, and Substile* quite through the Center. And that there may yet remain no Doubt, I have drawn all the four *Dials* in one, by which you may plainly see that there is no Difference between them, but what hath been already intimated. Only before I leave them, I will, (because these *Dials* are most in use) give you one other Example of an upright declining *Plain*, which by Reason of its great Declination from the *Prime Vertical*, or its *Poles* great Deviation from the Meridian, causeth the *Pole* to have but small Elevation, wherefore the *Dial* (as all such like) must be drawn without a Center, by the Directions following.

The four upright Declining Dials. Plate 3. Fig. 4.



C H A P. VIII.

How to draw the Hour-lines upon Upright far Declining Plains, which by Reason of the small Elevation, which the Pole hath over such Plains, the Hours (if they be drawn from a Center) cannot be of any competent Distance one from another.

THOSE *Plains* which lie near to the Meridian Circle, and whose *Poles* (consequently) near the *Prime Vertical Circle*, or Azimuth of East or West; the *Pole* hath but small Elevation above such *Plains*, so that the *Hour-lines* (especially those of them which fall near to the *Substile*) from the Center, cannot be drawn at any competent

petent Distance, without a large Extention of them. To remedy which Inconvenience, you may draw the Hour-lines for such a *Plain* at a convenient Distance, and in a little Room, without any Regard had to the Center. But before you proceed to draw the *Dial*, you must first find the three Requisites mentioned in the last Chapter, viz.

1. *The Height of the Pole above the Plain.*
2. *The Distance of the Substile from the Meridian.*
3. *The Plain's Difference of Longitude.*

Example of an Upright South Plain, declining Eastward 80 deg. in the Latitude of London 51 deg. 32 min.

To find these Requisites.

First, Draw the Circle Z H N O,
Plate 3. crossing it with the Diameters Z N,
Fig. 5. the Perpendicular, and H O, the Horizontal Line of the *Plain*.

Secondly, Because the *Plain* declineth 80 deg. Eastward, set 80 deg. from N to *a*, and from H to *b*.

Thirdly, Lay a Ruler to Z and *a*, it will cut the Horizon in S, the South Point thereof, and a Ruler laid to Z and *b*, will cut the Horizon in E, the East Point thereof.

Fourthly, Having the three Points Z S and N, through them draw the Meridian Z S N, whose Center (by any of the Ways before taught) will be found to be at *m*.

Fifthly,

Fifthly, Out of your Line of Chords take 51 deg. 32 min. the Latitude, and set them from O to *c*, and from N to *d*. Then laying a Ruler from E to *c*, it will cut the Meridian in P, the Pole of the World; through which Point P and Q, the Center of the Plain, draw the right Line P Q B, for the Axis of the World. Also the Ruler laid from E to *d*, will cut the Meridian in \mathcal{A} , so is \mathcal{A} one Point in the Meridian, through which the Equinoctial must pass, and R is another Point in the Meridian (extended) without the Circle, and a third Point is E, the East Point of the Horizon. Now forasmuch as these three Points R E \mathcal{A} , through which the Equinoctial is to be drawn, are almost in a strait Line, so that the Center of it will be at a very great Distance, we will forbear describing of that Circle, and content ourselves that we have found the Points R E \mathcal{A} , through which it should pass; because we shall draw the Hour-lines in this and the like Cases by other Means, and therefore I shall proceed to find the other Requisites. And,

1. *To find the Height of the Pole above the Plain, represented by P C.*—Take 90 deg. of your Line of Chords, and set them from *c* to *e*, a Ruler laid to *e* and P, will cut the Plain in *o*, so is *o C* the Height of the Pole (or *Stile*) above the Plain, viz. 6 deg. 12 min.

2. *To find the Distance of the Substile from the Meridian, represented by B N or Z c.*—Take the Distance B N or Z c (which is equal thereto) in

your Compasses, and measure it upon your Line of Chords, so you shall find

An Erect South Plain Declining Eastward 80 deg.
Plate 4. Fig. 1.

it

it to contain 38 deg. 4 min. which is the Distance of the *Substile* from the Meridian.

3. To find the *Plain's* Difference of Longitude, represented by the Angle $Q P \text{Æ}$. — Lay a Ruler upon P and Æ , it will cut the *Plain* in g, the Distance g B, measured upon the Line of Chords, will contain 82 deg. 8 min. the *Plain's* Difference of Longitude.

THESE three Requisites being thus found, I will now proceed to draw the *Dial*, without any Regard had to the Center.

How to draw the Hour-lines upon the Plain.

First, Draw a right Line A B, for the perpendicular Line of your *Plain*, and upon A as a Center, with 60 deg. or the Radius of your Chord, describe an obscure Arch of a Circle C D E, and thereon from C to D, set 38 deg. 4 min. the *Substile's* Distance from the Meridian before found, and draw the Line A D for the *Substile*, quite thro' the *Plain*.

Secondly, Take 6 deg. 12 min. the Height of the Pole above the *Plain* from your Chord, and set them upon the same Arch from D to E, and draw the Line A E for the *Stile*.

Thirdly, Forasmuch as the *Stile* A E in this Case is but of small Elevation, viz. but 6 deg. 12 min. Draw the Line G H parallel to A E, at such convenient Distance as you shall think fit, for your new (or augmented) *Stile* to stand from your *Substile* A D.

Fourthly, Assume any two Points in the *Substile* A D, as R and S, and through these two Points draw two infinite right Lines, both of them at right
Angles

Angles to the *Substilar* Line A D, as the Lines Z Z and XX.

Fifthly, From the Point R, take with your Compasses the least Distance to the new augmented *Stile* G H, and set that Distance upon the *Substilar* Line, from R to K: Also from the Point S, take the least Distance to the new *Stile* G H, and set that Distance also upon the *Substilar* Line from S to L.

Sixthly, Upon the two Points K and L (as upon two Centers) with 60 deg. or the Radius of the Line of Chords, describe the Portions of *Circles*, and in either of them set off 82 deg. 8 min. the *Plain's* Difference of Longitude, as from S to M, and from R to M, both on the same Side of the *Substilar* Line, on which the perpendicular Line of the Plain A B was drawn.

Seventhly, Divide either of the *Semicircles* last drawn into 12 equal Parts, at the Points ☉ ☉ ☉, &c. beginning this Division in either of them; at the Point M.

Eighthly, Lay a Ruler to the Point L, and every of the Divisions ☉ ☉ ☉, &c. and the Ruler will cut the Contingent or *Equinoctial* Line XX, in the Points * * * &c. Also a Ruler laid to K, and each of the Points ☉ ☉ ☉, &c. will cut the other Contingent Z Z, in the Points * * * &c.

Lastly, Lines drawn from the Point * in one Contingent Line, to the Point * in the other contingent Line, each to his Correspondent (which the *Substilar* Line will direct you how to do) those Lines shall be the true Hour-lines belonging to such a *Declining Plain*, and be drawn as in the Figure you see done, at a competent Distance one from another, without any Relation at all had to the Center of the Dial.

THUS

THUS have you finished your *Dial*, and in the making of this, you have made a South declining West 80 deg. also; for if you turn the Paper, and look through it, it will on the Backside be a South declining West 80 deg. only the Forenoon Hours in this, must be the Afternoon Hours in that: Nay, rather, you have in this one Dial made four, viz. a North declining either East or West, if you well observe what was said and done in the last Chapter.

AND thus have I done with all *Upright* or *Erect* Plains, either *Direct* or *Declining*. I shall now proceed to shew you how to inscribe Hour-lines upon such Plains as are not upright but *recline* from the *Zenith*, and of them there are such as are *Direct*, and such as do decline.



III. Of Reclining Plains.

CHAP. IX.

AS in upright Plains there were two Varieties, viz. *Erect Direct*, and *Erect Declining*; so are there of *Reclining Plains* also. For such *Reclining Plains* as do directly behold either the true *East*, *West*, *North*, or *South* Points of the Heavens, that is, whose Poles lie either in the *Meridian*, or *Prime Vertical Circle* of the Place, are called *Direct Reclining Plains*.

AGAIN, Those *Reclining Plains* which do not directly lie in, or their Poles be not in the prime Vertical or Meridian Circles of the Place, but deviate

deviate therefrom, are called *Declining Reclining Plains*. Of both which Sorts I shall give you an Account, and the manner of inscribing Hour-lines upon them, for in these Plains there is far more Variety, than there was in Upright or Erect Plains.



Of Direct Reclining Plains, &c.

I. Of East and West Recliners.

C H A P. X.

How to draw the Hour-lines upon a Direct East or West Reclining or Inclining Plain.

AS in upright declining Dials, two Things must be given, and three Things must be found, before the Hour-lines can be drawn; so in these direct reclining Plains, two Things must also be given, and three must be found, before the Dial can be made.

The Things that must be given, are

1. The Latitude of the Place.
2. The Reclination of the Plain.

THE Reclination of a Plain, (as hath been before declared) is the Arch of an Azimuth or Vertical Circle, intercepted between the Zenith of the Place, and the Reclining Plain.

Example

Example, Of an East or West Plain, Reclining 35 deg. in the Latitude of London, 51 deg. 32 min.

		d.	m.
Given	Latitude of the Place	51	32
	Reclination of the Plain	35	00

Required { The Height of the Pole above the Plain.
 The Distance of the Substile from the Meridian.
 The Plain's Difference of Longitude.

First, Draw the Circle N E S R, representing the Reclining Plain, and cross it with the two Diameters N Q S, the Horizontal-line of the Plain, and the Hour-line of 12 a Clock, and E Q R for the prime Vertical Circle.

Secondly, Because the Plain reclines 35 deg. take 35 deg. out of your Line of Chords, and set them from E to a, and from N to b.

Thirdly, Lay a Ruler from S to a, and it will cut the prime Vertical Circle in Z, so is Z the Zenith of the Place — Also a Ruler laid from S to b, will cut the same Vertical Circle in W, by which Point the Horizon of the Place must be drawn.

Fourthly, The Points Z and W being found, you have three Points through which you must describe the *East and West Inclining. Plate Meridian*, viz. N Z and S; and as many also through which you must draw the *Horizon*, namely, N W and S. The Centers of both which Circles will fall in the Line E Q R, (extended if need be) and

and the Manner how to find them, hath been often enough already taught.

Fifthly, Because the Latitude of the Place is 51 deg. 32 min. Take 51 deg. 32 min. from your Line of Chords, and set them upon your Plain from S to *c*. Then lay a Ruler upon W, the West-point of the *Horizon*, and the Point *c*, the Ruler will cross the *Meridian Circle* in P the Pole of the World; through which Point P and Q, the Center, (or Pole of the *Plain*) draw the right Line P Q, which shall be the Substilar Line of your Dial.

Sixthly, Take 90 deg. of your Line of Chords, and set them upon the Circle of your Plain from *c* to *d*, then lay a Ruler from W to *d*, and it will cut the *Meridian Circle* in *Æ*, so is *Æ* one Point in the *Meridian*, through which the *Æquinoctial Circle* must be drawn, and W the West Point of the *Horizon* is another; so have you two Points within the Circle, through which you must describe the *Æquinoctial Circle*, whose Center will be in the Line P Q, the Axis of the World, (extended if need be) the manner how to find it hath already been taught several Ways.

HAVING thus projected the *Meridian*, *Horizon*, and *Æquinoctial*, you may find the three Requisites, as followeth.

1. To find the Height of the Pole above the Plain P *k*, Lay a Ruler to *g* and P, it will cut the Plain on the Opposite side in *b*; so *k b* measured upon the Chords, will be 26 deg. 41 min. The Height of the Pole above the Plain.
2. To find the Distance of the Substile from the Meridian S *k*, Take S *k* in your Compasses, and measure it upon the Chord, it will be found

found 45 deg. 52 min. *The Distance of the Substile from the Meridian.*

3. *To find the Plain's Difference of Longitude,* Æ P Q , A Ruler laid from P to Æ , will cut the Plain in e , the Distance from O the Substile, to e will contain 66 deg. 27 min. of the Chord, which is *The Plain's Difference of Longitude.*

THESE Requisites being obtained, you may proceed to find the Hour Distances upon the Plain in this Manner.

Seventhly, Lay a Ruler to P the Pole, and Æ the Intersection of the Meridian with the Equinoctial, and it will cut the Plain in e . At e begin to divide the Semicircle into 12 equal Parts, at the Points $\odot \odot \odot$, &c.

Eighthly, Lay a Ruler to Q, and the several Points $\odot \odot \odot$, &c. and it will cut the *Equinoctial Circle* in the Points $*$ $*$ $*$, &c. dividing that into 12 unequal Parts.

Ninthly, Lay a Ruler to P, and the several Points $*$ $*$ $*$, &c. and it will cut the Plain in the Points $|| ||$, &c.

Lastly, If from the Center Q, you draw right Lines through the Points $|| ||$, &c. they shall be the true Hour-lines belonging to the *Reclining Plain*.

AND thus have you finished your *Dial*, and also in it 4 *Dials*: For the *Dial* as it here stands in the Scheme, is properly an East and West *Incliner*, but being turned upside down, as you see the Hours numbred, and the Word *Zenith* standing upwards, it is an East *Recliner*; and if the Hour-lines be turned, (or supposed to stand) on the right Hand of the prime Vertical Line E Q R , as in this Scheme they do on the left Hand, and the Hours

Hours of 4, 5, 6, &c. in the Morning changed to 8, 7, 6, in the Evening, the Plain is then a *West Recliner*. And if the Hour-lines be drawn through the Center of either of them, the Plains then become East and West *Incliners*; the Hours and Substile in all retaining the same Place, only the Denominations of the Hours changed, &c. you must remember, that in all East and West *Recliners*, the North Pole is elevated, and in all *Incliners* (opposite to them) the South Pole.



II. Of South Recliners.

CHAP. XI.

How to draw the Hour-lines upon Direct South Reclining or Inclining Plains.

IN the East and West Reclining and Inclining Plains, before described, the Meridian, or 12 a Clock Hour-line did lie in the Horizontal-line of the Plain, and the Poles thereof in the prime Vertical Circle. So (on the contrary) in these South and North Reclining and Inclining Plains, their *Horizontal Line* lieth in the prime Vertical Circle, or Hour of 6, and their Poles in the Meridian, and from hence they receive their Denomination.

OF these Direct Reclining Plains there are six Varieties, viz. Three of South Recliners, and as many of North Recliners. For,

1. THE South Plain may recline, so as it may just fall in the Axis of the World, and so pass through the Poles of the World, and then it is

D

called

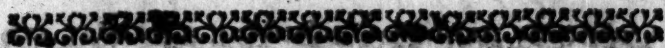
called an *Equinoctial Plain*, because the Poles thereof lie in the *Equinoctial Circle*, and neither of the Poles have any Elevation above it; wherefore the Hour-lines must be all parallel one to the other, and all of them to the Axis of the World, and the *Dial* must be drawn as the *Erect Direct East or West Dial* were. Only, whereas the Stile stood upon the Hour-line of 6 in the East and West, in these Plains it must stand upon the Hour-line of 12, and be of equal Height with the Distance between the Hours of 12 and 9, or 12 and 3, which are equidistant from the Meridian.

2. Or *Secondly*, The South Plain may so recline, that it may fall between the Zenith and the North Pole, and then is the South Pole elevated above such a Plain. Or,

3. The South Plain may so recline, that it may fall between the Horizon and the North Pole, and then is the North Pole elevated.

Examples of these three Varieties of South Reclining Plains do here follow.







The First Variety.


CHAP. XII.

How to draw the Hour-lines upon an Equinoctial Plain, or a Plain reclining just to the Pole.

FIRST, Draw the right Line A B, for the Horizontal Line of the Plain, and cross it about the Middle thereof at right Angles, with the Line 12 Q 12 for the Meridian and Hour-line of 12.

Secondly, Upon the Line 12 Q 12, either above or below Q, assume any Point, as S, and setting one Foot of your Compasses therein, (it being opened to the Radius of your Line of Chords) describe the Semicircle C D E, which divide into 12 equal Parts, beginning at D.

Thirdly, Lay a Ruler to S, and the several Points , &c. and it will cross the Equinoctial Line A B, in the Points , &c.

Lastly, Through these Points , &c. draw right Lines all parallel to the Line 12 Q 12; and so is your *A Direct Equinoctial Dial* finished.

THE Style may be either a *Plate 3. Fig. 6.*

strait Pin, of the Length of the Line Q S, set perpendicular to the Plain upon the Point Q; the Shadow of the Top thereof only giving the Hour. Or it may be a Plate of the Breadth of the Distance that is between the Hour-lines of 12 and 3, or 12 and 9, and then will the Shadow of the upper Edge thereof give the Hour of the Day.



The Second Variety.

C H A P. XIII.

How to draw the Hour-lines upon a Direct South Reclining Plain, which falls between the Zenith and the Pole.

Let the Example be of a *South Plain Reclining 25 deg. in the Latitude of London, 51 deg. 32 min.*

FIRST, Draw the Circle *W D E R*, cross it with the two Diameters *D R*, for the Meridian and Hour-line of 12, and *W E*, for the Horizontal Line of the Plain, and Hour-line of Six.

Secondly, Take 25 deg. the Plain's Reclination, out of your Line of Chords, and set that Distance from *D* to *a*, and from *E* to *b*.

Thirdly, A Ruler laid from *W* to *a*, will give *Z* the Zenith of the Place; and a Ruler laid from *W* to *b*, will give *S* the South point of the Horizon; both which Circles *W Z E*, the prime Vertical and *W R E* the Horizon,

Plate 4. may be drawn, as hath often enough Fig. 3. already been shewn, their Centers being always in the Meridian Line *D Q R*, extended, if need require.

Fourthly, Because the Pole of the World is always distant from the Zenith, the Complement of the Latitude of the Place, viz. here at London,

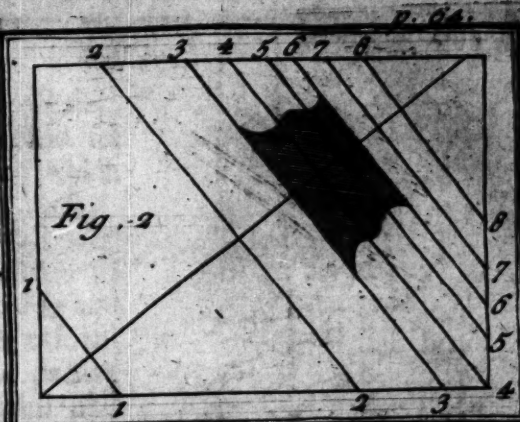
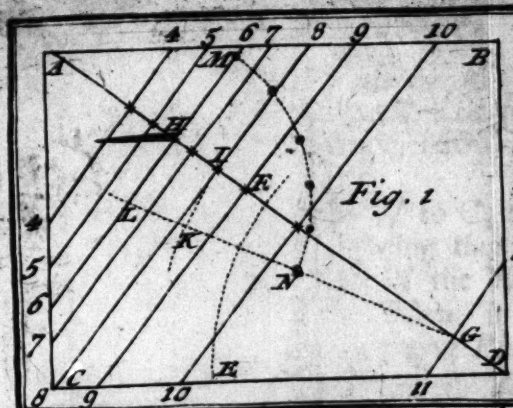
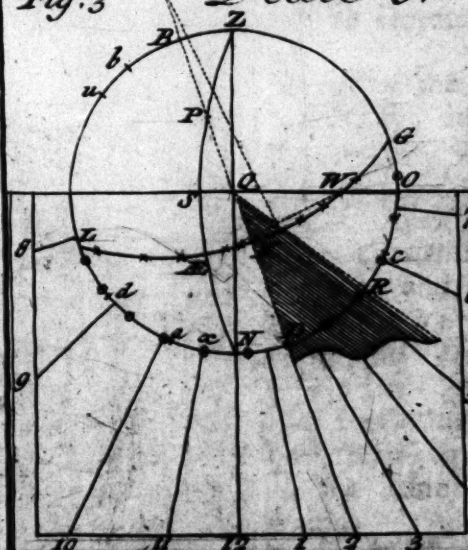


Fig. 3

Plate 3.



North Declining East, and South West, and South Declining West 24° 20'

North Declining North Declining East 24° 20'

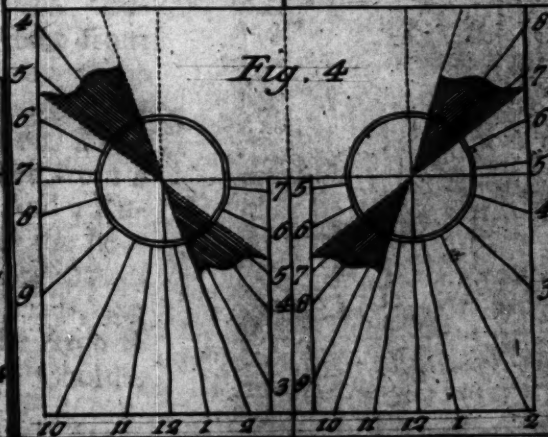


Fig. 5

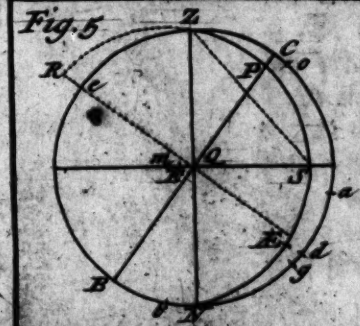


Fig. 6



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don, 38 deg. 28 min. Take therefore 38 deg. 28 min. out of your Line of Chords, and set them upon your Plain from *a*, (the Point which found the Zenith) to *C*.

Fifthly, Lay a Ruler from *W* to *C*, and it will cut the Meridian *DQR*, (being thus extended) in *P*, so is *P* the North Pole of the World, and because it falleth without the *Plain*, it is evident by the Scheme, that this reclining *Plain* passeth through the Meridian, between the Zenith and the Pole. And again, because the North Pole *P* falleth without the *Plain*, it also demonstrates, that the South Pole must be elevated above this Plain. Wherefore,

Sixthly, To find the Point of the South Pole upon the Meridian Line *DQR*, do thus. Because the two Poles are 180 deg. distant from each other, viz. two Quadrants, or twice 90 deg. Take therefore 90 deg. out of your Line of Chords, and set them twice upon your *Plain* from *C*, viz. first from *C* to *e*, and then from *e* to *n*, so shall the 180 deg. end in *n*: And a Ruler being laid from *W* to *n*, shall cross the Meridian in *A*, the South Pole; so is the South Pole *A* elevated above the Reclining Plain, the Quantity of *AR*, which is equal to the Arch *Rn*, which measured upon the Line of Chords, will be found 13 deg. 28 min.

Seventhly, Lay a Ruler from *W* to *e*, and it will cut the Meridian in *Æ*, so is *Æ* that point in the Meridian, through which the Equinoctial must pass. As also through the Points *E* and *W*, the East and West Points of the Horizon.

Eighthly, For the Hour-lines, they are to be drawn in all Respects as the Hour-lines were upon the upright South Plain, without any Alteration, only there the Stile was elevated accord-

ing to the Complement of the Latitude 38 deg. 28 min. here it must be elevated only 13 deg. 28 min. as in the Scheme. The manner how the Hour-lines are to be put on, I shall only repeat; but I shall forbear drawing them, leaving that to your own Practice, in regard there is no Alteration at all from the Erect Direct South Plain. Wherefore divide the Semicircle of your Plain W R E into 12 equal Parts, (beginning at R, and so 6 equal Parts on either Side of the Meridian D Q R.) Then lay a Ruler to Q, and every of those 12 Divisions, it will divide the Equinoctial into 12 unequal Parts. A Ruler laid from P to every of those unequal Parts in the Equinoctial, will divide the Plain into 12 other unequal Parts, through which last 12 unequal Parts, and the Center Q, if you draw right Lines, they shall be the true Hour-lines proper for the Plain.

And here by the Way note, For that the *Equinoctial Circle* in this Scheme is a very oblique Arch, the Center of it will be very remote, and the Hour-spaces upon it (as also upon the *Plain*) will be very close together in these small Draughts, which is occasioned by the small Elevation that the South Pole hath above this Plain, viz. but 13 deg. 28 min. which you might find without drawing of the Scheme, by subtracting 25 deg. the *Plain's* Declination, represented in the Scheme by the Line (or Circle) D Z, from Z P, the Complement of the Latitude of the Place. And therefore, foreseeing that the Pole hath but small Elevation above the Plain, and also what Pole, whether North or South that is elevated: The better Way

Way will be to augment the Stile, and to draw the *Dial* according to these following Directions.

How to draw the Hour-lines upon the Plain.

In the Scheme following, draw, *First*, The right Line W Q E, for the *Horizontal*, and perpendicular thereunto, the Line S Q R, for the Meridian and Hour-line of 12, which extend above the Horizontal Line to S.

Secondly, Upon S as a Center, with 60 deg. of your Chord, describe a small Arch of a Circle, and upon it set 13 deg. 28 min. the Height of the *South Reclining Pole* above the Plain from A 25 deg. Plate 4. to B, and draw the Line S B Fig. 4. for the Stile.

Thirdly, At any convenient Distance answerable to the Largeness of your Plain, draw a Line parallel to W E, as the Line C D F.

Fourthly, Set one Foot of your Compasses in D, and with the other take the nearest Distance to the Stile S B, which Distance set upon the Meridian from D to H.

Fifthly, Upon the Point H, (your Compasses opened to 60 deg. of your Line of Chords) describe the Semicircle K Q L, which divide into 12 equal Parts in the Points ○ ○ ○, &c.

Sixthly, Lay a Ruler unto H, and upon every of the Points ○ ○ ○, &c. and it shall cut the Equinoctial Line C D F, in the Points * * *, &c. through which the Hour-lines must pass: Wherefore, if from the Center S, and through the several Points * * *, &c. in the Line C D F, you draw strait Lines, bounding them between any

two Lines as W E, and M N, they shall be the true Hour-lines. Or,

Seventhly, If you draw another Tangent Line, and describe another Semicircle, and divide it, and the other Line, as you did the former, so shall the Lines drawn through the respective Points * * *, &c. in either of the Equinoctial (or Tangent Lines) be the true Hour-lines belonging to the Plain, without any Regard had to the Center at all, as you before did in Upright far Decliners.



The Third Variety.

C H A P. XIV.

How to draw the Hour-lines upon a Direct South Reclining Plain, which passeth between the Pole and the Horizon.

Let the Example be of a South Plain, Reclining 55 deg. in the Latitude of London, 51 deg. 32 min.

FIRST, Draw the Circle W N E R, for your Reclining-plain, cross it with two Diameters N Q R, the Meridian, and W Q E, the Horizontal-line of the Plain.

Secondly, Take 55 deg. the Plain's Reclination out of your Line of Chords, and set that Distance from N to *a*, and from E to *b*.

Thirdly, Lay a Ruler from W to *a*, it will cut the Meridian in Z, so is Z the Zenith of the Place, thro' which,

Plate 4.

Fig. 5.

which, and the Points W and E, draw the prime Vertical Circle W Z E.

Fourthly, Lay a Ruler from W to B, and it will cut the Meridian in S, the South Point of the *Horizon*, through which and the Points W and E, the *Horizon* of the Place W S E must be drawn.

Fifthly, The Pole being distant from the *Zenith* of the Place 38 deg. 28 min. equal to the Complement of the Latitude, set 38 deg. 28 min. from *a* to C, and a Ruler laid from W to C, shall cut the Meridian in P, the Pole of the World, and 90 deg. of your Line of Chords being set from C to *n*, and a Ruler laid from W to *n*, shall cut the Meridian in Æ through which and the Points W and E must the Equinoctial Circle be described: The Center whereof, as also of the *Horizon* and prime Vertical Circles are all in the Meridian N Q R, extended where need requires; and how these Centers are to be found, is shewed already.

Sixthly, For the drawing of the Hour-lines, they must be drawn as in the Erect Direct South Plain, or as was directed in the last Plain, and so I shall say no more of them in this place, only take Notice, that the North Pole is elevated above this Plain, the Quantity of the Arch N C, which is 16 deg. 32 min.

THESE are the three Varieties of South Direct Reclining Plains, and in the making of these you have also made the opposite Incliners as much; for each Plain hath two Faces, the one open to the *Zenith*, and the other to the *Nadir* of the Place.

III. Of North Direct Recliners.

C H A P. XV.

How to draw the Hour-lines upon a Direct North Reclining Plain.

AS in *South Reclining Plains* there were three Varieties, so also are there as many in the *North Recliners*. For,

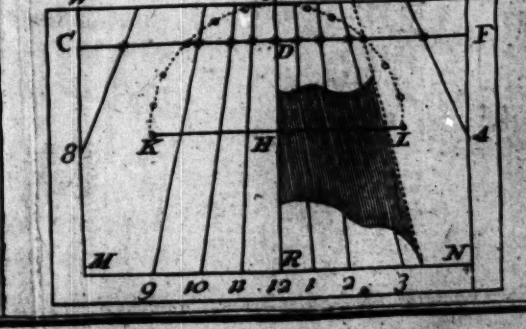
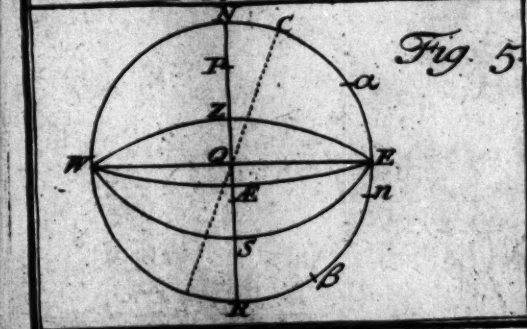
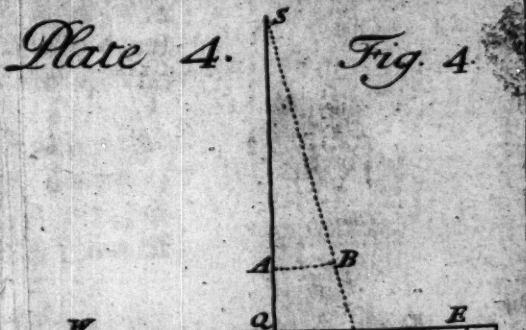
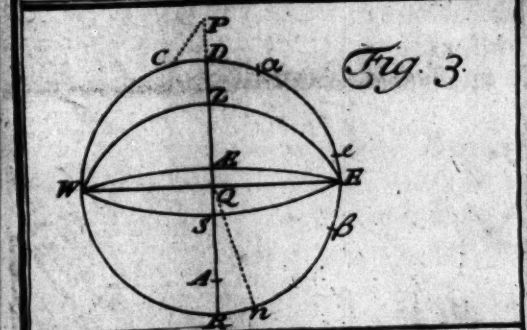
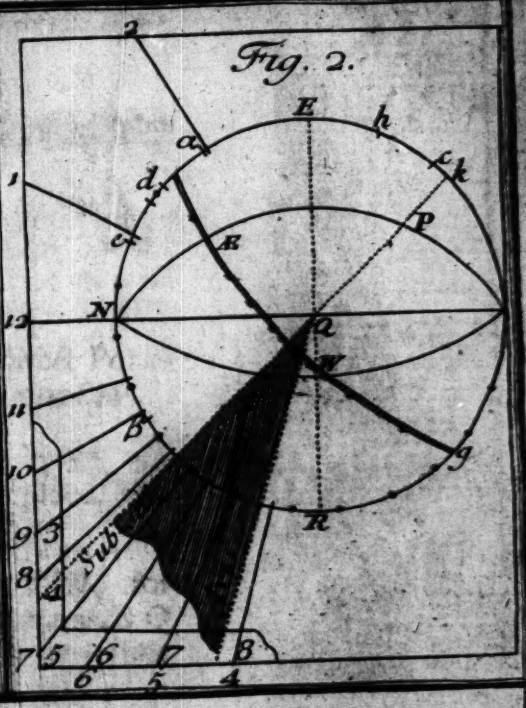
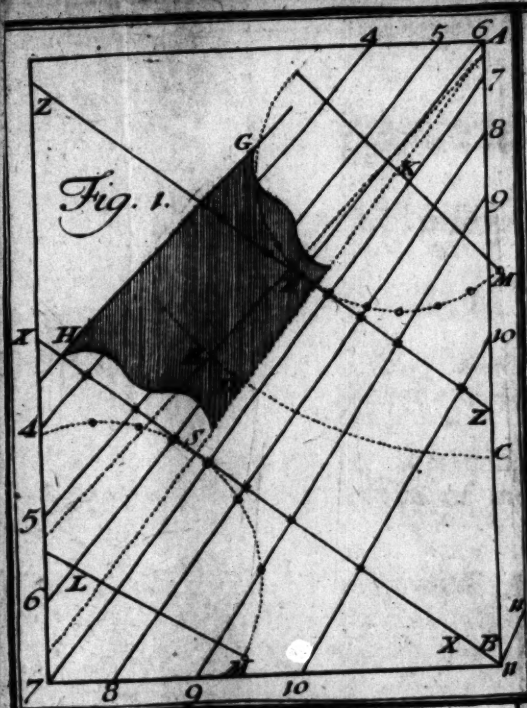
1. **THE North Plain** may so recline, that it may pass through the Meridian, just at the Intersection of the Meridian with the Equinoctial, the *Plain* it self lying in the Equinoctial Circle, and the Poles thereof in the Poles of the World, and so it is called, *A Polar-plain*. Or,

2. **THE Plain** may so recline, that it may cut the Meridian between the *Zenith* and the *Equinoctial*. Or,

3. It may recline so far, as to cut the Meridian between the Equinoctial and the Horizon.

Examples of these three Varieties of North Reclining Plains follow.

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The First Variety.

C H A P. XVI.

How to draw the Hour-lines upon a Direct Polar-plain, which reclineth just to the Equinoctial.

Example of a North-plain, Reclining 51 deg. 32 min. equal to the Latitude of the place, viz. London.

FIRST, Describe the Circle $E\AE WR$, for your Plain, cross it with the Diameters $\AE Q$ R , for the Meridian, and $W Q E$ for the prime Vertical Circle.

Secondly, Set 31 deg. 32 min. the Reclination of the Plain, (which in this Example is also equal to the Latitude of the Place) from \AE to a , and also from W to b .

Thirdly, A Ruler laid from E to a , will cut the North part of the Meridian in Z the Zenith of the place, and being laid from E to b , it will cut the Meridian in N , so is N the North point of the Horizon.

Fourthly, Through the Points W , Z and E , (by former Direction) draw the prime Vertical Circle, or Azimuth of East or West, $W Z E$. And also through W , N and E , draw the Horizontal Circle $W N E$.

Fifthly, Because the Pole of the World is always removed from the Zenith of the Place, so much as is the Complement of the Latitude (in this Example 38 deg. 28 min.) Set 38 deg. 28

min. from *a*, (the Point in the *Plain*, which found the Zenith Point *Z*,) Northward of the Zenith, and the Compass-point will fall in *W*, the West-point of the Horizon; so that if a Ruler were laid from *W* to *E*, it would cut the Meridian in *Q*, for the Pole of the World, which is already the Center of the Plain, so that the Pole of the World, and the Pole of the Plain, fall both in one Point, and the Pole *Q* is elevated above the Plain 90 deg. viz. the Quan-

A Direct Polar quantity of the Meridian Line *Æ*
North Dial. Plate *Q*, or rather the Arch *Æ W*,
 5. *Fig. 1.* which is the Measure thereof.

Sixthly, To draw the Hour-lines upon this Plain, it is easiest of all others, for if you divide the Semicircle *E R W*, into 12 equal Parts in the Points *⊙ ⊙ ⊙*, &c. and through those Points draw strait Lines from the Center *Q*, they shall be the true Hour-lines belonging to this *Polar-plain*.

AND this Plain, by Reason of its North Reclination, is, in Summer, capable of receiving all the Hours from Sun-rising to Sun-setting, and therefore the Hour-lines of 4 and 5 in the Morning, and of 7 and 8 at Night, must be drawn through the Center, as you did in the Vertical or Horizontal Dial, and as you see here done in this Figure.

THE Stile of this Dial must be a strait Pin or Wire, set perpendicular upon the Plain, from the Center *Q*, and of any Length. And this for the first Variety of North Recliners.

THE South Inclining Plain opposite to this, is directly the same, only the Forenoon Hours in this must be the Afternoon Hours in that, and the Hours of 4 and 5 in the Morning, and of 7 and 8 in the Evening, must be omitted.

The



The Second Variety.

C H A P. XVII.

How to draw the Hour-lines upon a North Reclining Plain, which intersects the Meridian between the Zenith and the Equinoctial.

Let the Example be of a North Plain, Reclining
25 deg.

FIRST, Draw the Circle *ESWR*, representing your North Reclining Plain, and cross it with the two Diameters *SQR*, the Meridian of the Place, and *EQW*, the Horizontal Line of the Place.

Secondly, Set the Reclination of the Plain 25 deg. from *S* to *a*, and from *W* to *b*.

Thirdly, Lay a Ruler from *E* to *a*, it will cut the Meridian in *Z* the Zenith. And a Ruler laid from *E* to *b*, will cut the Meridian in *N* the North Point of the Horizon: So have you three Points *E Z* and *W*, whereby to draw the prime Vertical Circle *E Z W*, and three Points also, viz. *E N* and *W*, whereby to draw the Horizon *E N W*.

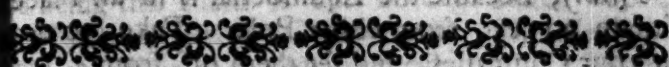
Fourthly, Because the Equinoctial is always 90 deg. distant from either of the Poles, set 90 deg. upon your Plain, from *c* to *d*. Then laying a Ruler to *E* and *d*, it will cut the Meridian in *Æ*, so is *Æ* the Point of the Intersection of the Equinoctial, with the North part of the Meridian; wherefore through the Points *E Æ W*, describe
the

the Equinoctial Circle; the Center whereof, as also of the Horizon, and prime Vertical
Plate 5. Circle, will fall in the Meridian *SQR*,
Fig. 2. extended where need requires.

Fifthly, The *Horizon*, *Equinoctial*, and *Pole* being thus seated in their true Positions upon the *Plain*, the Thing required in this Dial, is, *The Height of the Pole above the Plain*, which may be found in this Manner. — Lay a Ruler from *E* to *P*, and it will cut the *Plain* in *c*, the Distance *Sc*, measured upon your Line of Chords, will contain 63 deg. 28 min. which is the Height of the *Pole* above the *Reclining Plain*.

Lastly, For the drawing of the Hours, that is done the same Way as in the Erect Direct South *Plain*, only here the *Stile* must be elevated above the *Meridian Line* 63 deg. 28 min. whereas there it was only 38 deg. 28 min. the Complement of the Latitude. The *North Pole* is elevated above this *Plain*, and the Hours that the *Plain* is capable to receive, are 4, 5, 6, 7, 8 and 9 in the Morning, and 3, 4, 5, 6, 7 and 8 at Night.

THE Height of the *Pole* (or *Stile*) above this *Plain* may be found by adding the Complement of the Latitude 38 deg. 28 min. and 25 deg. the Reclination together, the Sum whereof is 63 deg. 28 min. the Height of the *Stile*, as before.



The Third Variety.

C H A P. XVIII.

How to draw the Hour-lines upon a Direct North Reclining Plain, which intersects the Meridian between the Equinoctial and the Horizon.

Let the Example be of a Direct North Plain, Reclining 70 deg. in the Latitude of London, 51 deg. 32 min. Plate 5. Fig. 3.

FIRST, Draw the Circle E S W R, representing your North Reclining Plain, and cross it with the two Diameters S Q R, for the Meridian of the Place, and with E Q W the Horizontal Line of the Plain.

Secondly, Set the Reclination of the Plain 70 deg. from S to *a*, and from W to *b*.

Thirdly, Lay a Ruler to E and *a*, it will cut the Meridian in Z the Zenith, through which, and the Points E and W, draw the prime Vertical Circle E Z W. — Also, lay a Ruler from E to *b*, it will cut the Meridian in N, the Intersection of the Meridian with the North Part of the Horizon; now through the Points E N and W, describe the Horizon of the Place E N W.

Fourthly, Forasmuch as the Pole is distant from the Zenith of the Place 38 deg. 28 min. (equal to the Complement of the Latitude) set 38 deg. 28 min. from *a*, the Point which gave the Zenith Z to *c*, and lay a Ruler from *e* to *c*, so shall it cross the Meridian in P, the Pole of the World.

Fifthly,

Fifthly, Because the Equinoctial is in all Places situate 90 deg. from either Pole. Take 90 deg. in your Compasses, and set them off from *c*, (the Point which gave the Pole *P*) both ways, to *e* above, and to *g* below. So a Ruler laid from *E* to *g*, will cut the Meridian (it being extended) in *Æ*, without the Plain, which shews that the North Part of the *Equinoctial Circle* lies below this *Plain*. Therefore lay a Ruler from *E* to *e*, and it will cross the Meridian in *Æ* above: So is *Æ* the Point where the Meridian, and the South-point of the *Equinoctial* will intersect, and thro' that Point and the Points *E* and *W*, must the *Equinoctial E. Æ W.* be drawn.

Sixthly, The *Horizon*, *Pole*, and *Equinoctial*, being thus projected, the Thing required in this Plain, is, *The Height of the Pole above it*, viz. *P R*, which may be found in this manner. — Lay a Ruler from *E* to *P*, and it will cut the Plain in *c*, the Distance from *R* to *c* measured upon the Chord, will be 71 deg. 32 min. which is the Height of the Pole above this Reclining Plain. — Or the Height of the Pole above the Plain may be found, by adding the Plain's Reclination 70 deg. to 38 deg. 28 min. the Complement of the Latitude, the Sum whereof 108 deg. 28 min. which taken from 180 deg. the Remainder will be 71 deg. 32 min. as before.

Lastly, For the drawing of the Hour-lines, they are done in all Respects as those before in South Erect Plains, only in this make the Elevation of the *Stile* 71 deg. 32 min. as you find it by your Projection.

YOUR Hour-lines being drawn, erect the *Stile* 71 deg. 32 min. above the Meridian or Substile, letting it point up to the North Pole, because that Pole above this Plain is so much elevated; and

and being this Plain is but 20 deg. raised above the Horizon, viz. the Complement of his *Reclination*, the Plain is capable to receive all the Hours from 4 in the Morning to 8 at Night, and therefore the Hours of 4 and 5 in the Morning, and 7 and 8 in the Evening, must be drawn through the Center, as was done in the *Vertical* or *Horizontal Dial*. *Plate 5. Fig. 3.*

AND thus have you had Examples of all the Varieties both of *East, West, North, and South Reclining* Plains; and no other can possibly fall out in any Place whatsoever. The *Inclining* Plains are the same with the *Recliners* opposite to them; and must be drawn in the same manner as hath been (in some Measure) heretofore hinted, and shall be more at large discoursed of hereafter, when I have done with *Declining Reclining* Plains, of which I come now to treat.

IV. Of *Declining Reclining* Plains.

CHAP. XIX.

AS there were six Varieties of *Direct North* and *South Reclining* Plains, so also are there of *South* and *North Declining Reclining* Plains, viz. Three Varieties of *South Recliners Declining*, and as many of *North Recliners Declining*. For in *South Recliners Declining*,

1. THE

1. THE *Declining* may be such, that the *South Reclining Plain* may cut or fall upon the *Meridian*, just upon the *Pole-point*; and such *Reclining Declining Plains*, are called *Equinoctial Decliners*: Or,

2. THE *Declination* may be such, that the *Reclining Plain* shall intersect the *Meridian* between the *Zenith* of the *Place*, and the *Pole* of the *World*: Or,

3. THE *Declination* may be such, that the *Reclining Plain* shall cross the *Meridian* between the *Pole* and the *Horizon*.

These are the three Varieties of South Recliners Declining. In North Recliners Declining there are three other Varieties. For,

1. THE *Declination* may be such, that the *North Reclining Plain* may cross the *Meridian* in the *Point* where the *Equinoctial* intersects the *Meridian*. And then such *Plains* are called *Polar Declining Plains*, because the *Poles* of them lie in the *Axis of the World*, and the *Substile* in such *Plains* will be always perpendicular to the *Meridian* of the *Place*.

2. THE *Declination* may be such, that the *Reclining Plain* may intersect the *Meridian*, between the *Zenith* and the *Equinoctial*: Or,

3. THE *Declination* may be so much, that the *Reclining Plain* may fall upon the *Meridian*, between the *Equinoctial* and the *Horizon*.

Examples of all these Varieties follow.



Is Of South-Recliners.

The First Variety.

CHAP. XX.

How to draw the Hour-lines upon a South-Reclining Declining Plain, which cutteth the Meridian in the Pole Point.

IN Declining Reclining Dials, before the Hour-lines can be drawn, Three Things must be given, and four Things found : The Things given are,

- Given {
1. The Latitude of the Place.
 2. The Declination of the Plain,
 3. The Plain's Reclination.

The Things required, are,

- Required {
1. The Distance of the Meridian and Horizon.
 2. The Height of the Pole above the Plain.
 3. The Distance of the Substile and Meridian.
 4. The Plain's Difference of Longitude.

Let

Let the Example be of a South Plain Declining East, 30 deg. and Reclining 34 deg. 32 min. in the Latitude of London, 51 deg. 32 min.

First, Draw the Circle H A O R, and cross it with the two Diameters H Q O, the Horizontal Line of the Plain, and A Q R, the perpendicular Line of the Plain, crossing each other at right Angles in Q, the Center of the Plain.

Secondly, Because the Plain reclined 34 deg. 32 min. Take 34 deg. 32 min. from your Line of Chords, and set them upon your Plain from A to a, from H to b, and from R to c.

Thirdly, Lay a Ruler from O to a, and it will cut the perpendicular Line of the Plain in Z the Zenith of the Place. Also a Ruler laid from O to b, will cut the Plain's Perpendicular in K, the Intersection of the Horizon of the Place, with the Plain's Perpendicular. And a Ruler laid from O to c, will cut the perpendicular of the Plain A R, (it being extended) in N the Nadir-point. Having found these Points upon the perpendicular Line of the Plain.

Fourthly, Through the Points H K O, draw the Horizon of the Place. And,

Fifthly, Because the Plain declines 30 deg. Eastward, take 30 deg. out of your Chord, and set them from R to d, and from O to e; and laying a Ruler from Z the Zenith to e, it will cross the Horizon in E, the East point thereof, and the Ruler laid from Z to d, will cross the Horizon in S the South point thereof; so have you found three Points, viz. Z N and S, through which you may draw the Meridian, whose Center you may find,

find, as hath been before taught : Or in this Manner,

DIVIDE the Space between Z and N in two equal Parts in C, and through C draw the Line C D parallel to Q O, extending it as you shall have Occasion. Also from Q, through E, draw another Right Line Q E, extending it, as Occasion shall offer ; the Point of those two Lines Intersection is the Center of the Meridian. Which being drawn,

Sixthly, Lay a Ruler from E the East point of the Horizon to Z the Zenith, and it will cut the Plain in *b*. And because the Pole of the World is distant from the Zenith 38 deg. 28 min. equal to the Complement of the Latitude, set 38 deg. 28 min. from *b* upon the Plain, and it will fall just upon P, which is the Point of the Plain's Intersection with the Meridian, which demonstrates the Pole to have no Elevation above the Plain, and so the Plain to be *Equinoctial Declining*.

Seventhly, Draw the Line P Q L for the Axis of the World, and because the Equinoctial Circle is in all Parts distant from either Pole 90 deg. set 90 deg. from P or L, to \mathcal{A} ; and through Q, draw the Line \mathcal{A} Q \mathcal{A} , for the Equinoctial Circle, which is here a strait Line, and being extended, would pass through the Center of the Meridian, and also through the East and West Points of the Horizon, as it ought to do.

THE Scheme being thus projected, the four Requisites from it are easily obtained. For,

1. To find the Distance of the Meridian, and the Horizon O P. The Arch O P measured upon

your

your Line of Chords, will contain 71 deg. 53 min. the Distance required.

2. *The Height of the Pole above the Plain* (the point P) 00 deg. 00 min. therefore it is an Equinoctial Declining Plain.

3. *The Distance of the Substile and the Meridian*, the Point P also. Therefore that, as also all the Hours must be parallel to the Substile.

4. *To find the Plain's Difference of Longitude*, Q P B. Lay a Ruler from P to B, and it will cut the Plain in m, the Distance L M measured upon your Chord, is the Plain's Difference of Longitude 24 deg. 19 min.

THESE Requisites being thus found, I will now shew,

How the Hour-lines are to be drawn upon the Plain.

First, Draw a Line as B A C for the Horizontal Line of your Plain, and upon any convenient Point therein, as upon A, with 60 deg. or the Radius of your Line of Chords, describe the Semicircle B D C.

Secondly, From your Line of Chords take 71 deg. 53 min. the Distance of the Meridian and Horizon, and set them from B to D, and draw the Line A D for the Substile.

Thirdly, Take 24 deg. 19 min. the Plain's Difference of Longitude, and that Distance from D to E, and draw the Line A E.

Fourthly, Divide the Semicircle B C D into 12 equal Parts at the Points ☉ ☉ ☉, &c. beginning the Division at the Point E.

Fifthly, Through the Point O, (or any other Point taken at all Adventures in the

the Substilar Line) draw a Line M O N at right Angles, (or perpendicular) to the Substilar, representing the Equinoctial.

Sixthly, Lay a Ruler from A, and every of the Points $\odot \odot \odot$, &c. in the Semicircle, and it will cross the Equinoctial in the Points $***$, &c.

Lastly, If through these Points $***$, &c. you draw right Lines parallel to the Substilar, they shall be the true Hour-lines belonging to your *Plain*, the Hour-line of 12 being that where you began to divide your Semicircle, that is, at the Mark (or $*$) which was made from the Point E.

FOR the Stile of this Dial, it may be either a strait Pin or Wire, of the just Length of the Line A O, erected perpendicularly upon some Point of the Substile (as at A or O) the very Top of the Shadow thereof, giving the Hour among the Hour-lines upon the Dial.

OR else the Stile may be a Plate of Brass or Iron of the Breadth of A O, set perpendicular to the *Plain*, upon the Substilar Line A O D, the Shadow of whose upper Edge shall give the true Hour of the Day!



Required
1. The Distance of the Meridian and
Horizon.
2. The Height of the Pole above the
Plain.
3. The Length of the Substile and the
Meridian.
4. The Plain's Difference of Longitude.

First, Describe the Circle H A O R, representing
your Rectifying Plane, and cross it with
right Angles, with the two Diameters A R, and



The Second Variety.

C H A P. XXI.

How to draw the Hour-lines upon a South Reclining Plain, Declining East or West, which passeth between the Zenith and the Pole.

IN this, as in all other Decliners Reclining, three Things must be known, and four must be found before the Drawing of the Hour-lines.

Let the Example be a South Reclining Plain, Declining East 30 deg. and Reclining 20 deg. in the Latitude of 51 deg. 32 min. London.

Given	{	1. Latitude of the Place	51 32
		2. Declination South East	30 00
		3. Reclining South.	20 00

Required	{	1. The Distance of the Meridian and Horizon.	
		2. The Height of the Pole above the Plain.	
		3. The Distance of the Substile and the Meridian.	
		4. The Plain's Difference of Longitude.	

First, Describe the Circle H A O R, representing your Reclining Declining Plain, and cross it at right Angles, with the two Diameters A R, for the

the Perpendicular, and H O, for the Horizontal Line of the Plain.

Secondly, Take 20 deg. the Plain's Plate 5. Reclination, out of your Chord, and Fig. 6. set them from A to *a*, from O to *b*, and from R to *c*.

Thirdly, A Ruler laid from H to *a*, will give you Z the Zenith, and laid from H to *b*, will give you K the Intersection of the Horizon with the perpendicular Line of the Plain. And the Ruler laid from H to *c*, will give you N the Nadir, then through the points H, K and O, draw the Horizon H K O.

Fourthly. Take 30 deg. the plain's Declination out of your Line of Chords, and set them from R to *d* westward, (because the Plain declines Eastward) and also from O to *e*, so a Ruler being laid from Z to *e*, shall cut the Horizon in E, the East point thereof, and laid from Z to *d*, shall cut the Horizon in S, the South point thereof. Thus have you three Points Z, S and N, through which to draw the Meridian Circle, which you may extend without the plain to P and N, occasion sometimes requiring it should be so.

Fifthly, Forasmuch as the Pole of the World is always distant from the Zenith equal to the Complement of the Latitude of the place, as here at London, 38 deg. 28 min. Lay a Ruler from E to Z, and it will cut the Plain in *b*, from whence set 38 deg. 28 min. to *k*. So a Ruler laid from E to *k*, will cut the Meridian (extended) in the point P, the North pole of the World. And a Ruler laid from P to Q, shall cross the Meridian in L, the South-pole, and the Line P Q L, shall be the Axis of the World.

Sixthly, Take 90 deg. of your Chords, and set them from *k* (the point which found the pole at P)

E

to

to n : So a Ruler laid from E to n , shall cut the Meridian in B , through which point, and through the point E , the *Equinoctial Circle* must be described, whose Center will be in the Axis PL extended, and the Manner how to find it, hath been several Times already discovered.

THE *Horizon*, *Meridian* and *Equinoctial Circle* being thus described upon your Plain, by their Intersections and Distances, the four Requisites belonging to this *Declining Reclining Plain* may be obtained. As,

1. To find the Distance of the Meridian and Horizon HV . The Distance HV upon the Plain, measured upon the Line of Chords will contain 78 deg. 50 min. the Distance of the Meridian and Horizon.
2. To find the Height of the Pole or Stile, above the Plain Lc . Set 90 deg. from c to b , then lay a Ruler from b to L , and it will cut the plain at m , the Distance from c to m , measured upon your Chords, will contain 13 deg. 40 min. the Height of the Pole or Stile above the Plain.
3. To find the Distance of the Substile from the Meridian Vc , measure the Distance Vc upon the Line of Chords; and it will contain 7 deg. 30 min. the Distance required.
4. To find the Plain's Difference of Longitude, BLD . Lay a Ruler from L to B , it will cut the plain in b , so the Distance ba measured upon the Line of Chords, will contain 28 deg. 52 min. the plain's Difference of Longitude.

THUS

THUS are the four Requisites belonging to this *Plain* found, and in this Example, two Things are very observable.

1. WHEREAS *P* the North-pole of the World, falls without the *Plain*, and the point *L*, representing the South Pole, falls within the *Plain*, it denotes that the South pole must be elevated.
2. IN respect that the Line or Arch *L c*, which is the Height of the Stile or Pole above the *Plain*, is but of small Quantity, viz. 13 deg. 40 min. it will from thence follow, that the *Equinoctial* Center will be very remote, and that the Hour-lines near to the Substile will be very close, so that in small *Dials* their Distances one from another will be insensible; and therefore you may save the Labour of describing the *Equinoctial Circle*, and be satisfied in finding of the point *B*, by which the *Plain's* Difference of Longitude is found. For, in such Cases as this, the *Plain's* Difference of Longitude, the Distance of the Meridian from the Horizon, and of the Substile's Distance from the Meridian, and the Height of the *Pole* above the *Plain* being gained, you may proceed to draw the *Dial* as followeth, not much differing from the drawing of the Upright far declining *Dial*, Chapter VIII.

How to draw the Hour-lines upon the Plain.

First, Draw a right Line *A B C* for the *Horizontal* Line of your *Plain*, and assume any convenient Place therein, as *B* for a Center; upon
E 2
which

which point, with 60 deg. of any large Line of Chords, (*For it is necessary, not only in this, but for divers other Occasions, to have several Lines or Scales of Chords upon your Ruler, or else use a Sector, which*

South Declining East 30 deg. Reclining 20 deg. Plate 5. Fig. 7. describes the Arch of the Circle A D. Upon this Arch, from A to D, set 78 deg. 50 min. the Distance of the Meridian from the Horizon, and note the point E, but you need not draw the Meridian Line.

Secondly, From D to E set 7 deg. 30 min. the Distance of the Substile from the Meridian, the same way as you find it to lie in your Projection, and draw the Line B E for the Substile. Also upon the same Arch, set off 13 deg. 40 min. the Height of the Stile from E to F, and draw the Line B F for the Stile. Which being but of small Elevation, viz. 13 deg. 40 min. ought to be augmented; and therefore (at any convenient Distance suitable to the Bigness of your Dial-plain) draw a Line as G H, parallel to B F, for your augmented Stile or Axis.

Thirdly, Through any two Points taken at Adventure in the Substilar Line, as K and L, draw two right Lines perpendicular, or at right Angles to the Substilar, as the Lines M K N, and O L P. Then from the Point K, take the least Distance to the augmented Stile G H, and set that Distance upon the Substilar K to Q. Also from the Point L, take the nearest Distance to the augmented Stile G H, and set that Distance upon the Substilar from L to R.

Fourthly Upon the Points Q and R, as upon two Centers, with 60 deg. of any of your Chords, describe two Semicircles (or other Portions of

Cir-

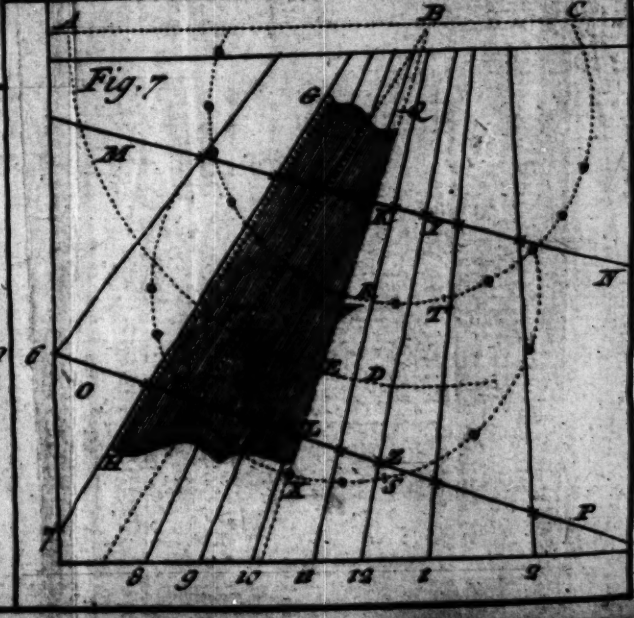
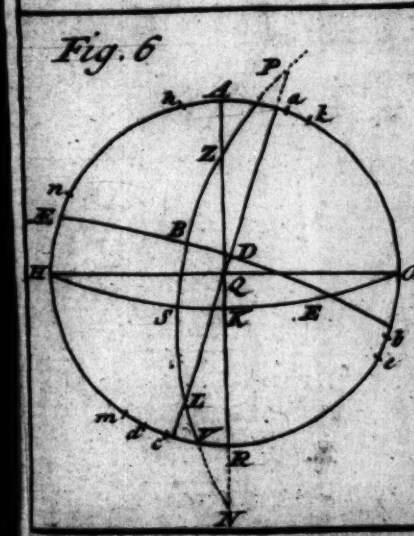
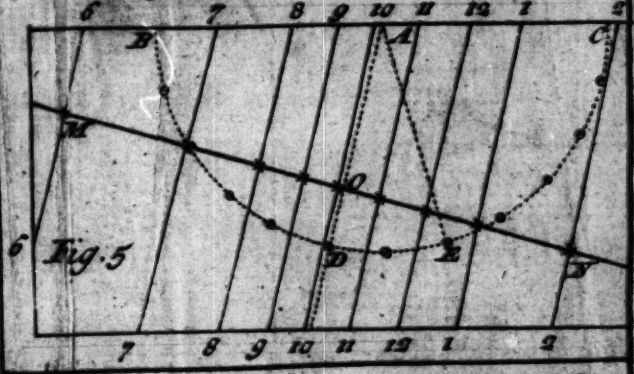
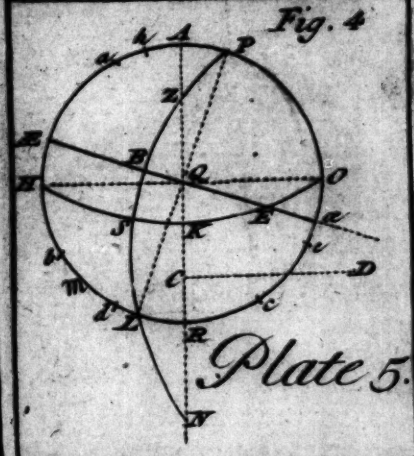
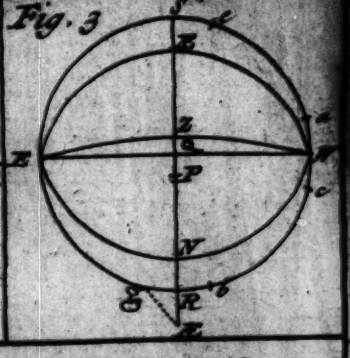
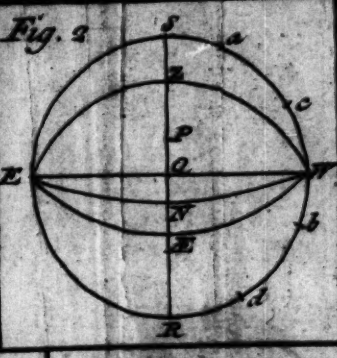
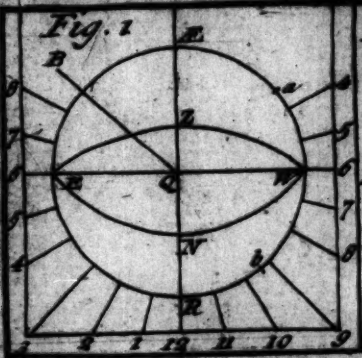


Plate 5.

Circles) and in either of them set 28 deg. 52 min. from V to T upon one of them, and from X to S upon the other.

Fifthly, Lay a Ruler from Q to T, and it will cut the Tangent Line in Y: Also lay a Ruler from R to S, and it will cut the other Tangent Line in Z, and a right Line drawn through the Points Y and Z, shall be the Hour-line of 12.

Sixthly, At the Points S and T, begin to divide the several Semicircles in 12 equal Parts or Hours, by taking 15 deg. of your Chord, and setting them from S and T both ways at the Points $\odot \odot \odot$, &c. so many Times as the *Plain* will receive Hour-lines.

Seventhly, Lay a Ruler from the Points Q and R, to every of the Points $\odot \odot \odot$, &c. in their respective Semicircles, and it will cross their several Tangent Lines in the Points ***, &c.

Lastly, Through the Points ***, in both the Tangent Lines, draw right-lines, each to his Correspondent, which the Hour-line of 12 will direct you how to do, and those shall be the true Hour-lines of your *Plain*.

For the Stile of this *Dial*, it may be either of Wire or Plate, containing an Angle equal to the Height of the Pole above the *Plain*, but it must be augmented answerable to the augmented Stile, as you see in the Figure, and must be set in its proper Place upon the Substilar Line, and also perpendicular or square to the *Plain*, and so is this *Dial* finished.



The Third Variety.

C H A P. XXII.

How to draw the Hour-lines upon a South Reclining Plain, declining East or West, which intersects the Meridian between the Pole and the Horizon.

LET the Example for this third and last Variety of South Declining Reclining Plains be of a South Plain declining Eastward 30 deg. and reclining 55 deg. in the Latitude of 51 deg. 32 min. viz. London.

		<i>d.</i>	<i>m.</i>
Given	1. The Latitude of the Place.	51	32
	2. The Declination Eastward	30	00
	3. The Reclination.	55	00

Required	1. The Distance of the Meridian from the Horizon.	
	2. The Height of the Pole or Stile above the Plain.	
	3. The Substile's Distance from the Meridian.	
	4. The Plain's Difference of Longitude.	

First, Draw the Circle A H R O, for your reclining declining Plain, and cross it with the two Diameters A R the Vertical, and H O the Horizontal Line of the Plain,

Secondly,

Secondly, Set 55 deg. the *Plain's* Reclination from A to *a*, and from O to *b*.

Thirdly, Lay a Ruler from H to *a*, (*Pl. 2. Fig. 5.*) and it will give you Z the Zenith, and laid from H to *b*, it will give you K, the Point of the Horizon's Interfection with the *Plain's* Vertical Line. So have you three Points H K and O, through which to describe the Horizon of the Place H K O.

Fourthly, Set 30 deg. the *Plain's* Declination from R to *c* Westward, (because the *Plain* declines Eastward) and from O to *d*. So a Ruler laid from Z to *c*, shall give you S, the Interfection of the Meridian with the South point of the *Horizon*. And the Ruler laid from Z to *d*, shall give you E the East point of the *Horizon*.

Fifthly, Having the Points S and Z, through them you may draw the Meridian Circle L S Z P, as hath been already several ways taught, the Center whereof will fall in the Line Q E being extended.

Sixthly, Lay a Ruler from E to Z, and it will cut the *Plain* in *e*, from which Point *e*, set 38 deg. 28 min. to *f*, and a Ruler being laid from E to *f*, shall give the point P, upon the Meridian Circle for the Pole of the World. And a right Line drawn from P through Q, shall be the Axis of the World, and the Subtilar Line of the *Dial*.

Seventhly, Set 90 deg. from *f* to *h*, (because the *Equinoctial Circle* is in all places 90 deg. distant from either Pole P or L.) So laying a Ruler from E to *h*, it will give you the point B in the Meridian, through which, and E, the East point of the Horizon, the *Equinoctial Circle* must pass, may be drawn as in former Examples, the Center thereof being in the Axis of the World, P L extended.

THESE three principal Circles, viz. the *Horizon*, *Meridian* and *Equinoctial*, being described, according to their true Situations upon the *Plain*, the same forementioned Requisites may from thence be easily deduced, as followeth.

1. To find the Distance of the *Meridian* from the *Horizon* O C. The Arch O C, measured upon the Line of Chords, will contain 64 deg. 41 min. The *Substile's* Distance from the *Meridian* C D. This Arch measured will contain 6 deg. 2 min. The Distance of the *Substile* from the *Meridian*.
2. To find the Height of the Pole or *Stile* above the *Plain* P D. Set 90 deg. from D to ∞ , and lay a Ruler from ∞ to P, it will cut the *Plain* in m, the Arch D m measured on the Line of Chords, will contain 19 deg. 25 m. The Height of the *Stile*.
3. To find the *Substile's* Distance from the *Meridian* C D. This Arch measured will contain 6 deg. 2 min. The Distance of the *Substile* from the *Meridian*.
4. The *Plain's* Difference of Longitude B P Q. A Ruler laid from P to B, will cut the *Plain* in k. So the Distance F k measured, will be 17 deg. 38 min. The *Plain's* Difference of Longitude.

THESE Requisites being thus found, you may proceed to draw the Hour-lines in this as in other *Plains*. First, By laying a Ruler upon P the Pole of the World, to B, in the Intersection of the *Meridian* and *Equinoctial*, which will cut the *Plain* in k, at which point, begin to divide the Semicircle into 12 equal Parts. And from Q, to each of them, lay a Ruler crossing the *Equinoctial Circle*, and dividing that into 12 unequal parts, to which unequal Parts of the *Equinoctial*, a Ruler

ler laid, it will divide the *Plain* into 12 other unequal parts, through which, and the Center Q, right Lines being drawn, they shall be the true Hour-lines proper for the *Plain*.

But in this Example, the Elevation of the Pole or Stile above the *Plain*, being but small, viz. 19 deg. 25 min. you may, if you please, draw the Hour-lines by one Tangent-line, and the Center, as was shewed in the second Variety of Direct South Reclining Plains; and as here followeth.

How to draw the Hour-lines upon the Plain.

First, Upon your *Plain*, towards the Bottom thereof (because the North Pole is here elevated) draw a right Line A B, parallel to the Horizon, and assume A for the Center of your Dial, upon which point, with 60 deg. of your Chords, describe an Arch of a Circle B E, upon which from B, set the Distance of the Meridian and Horizon, 64 deg. 41 min. to C, and draw the Line A C for the Hour-line of 12. Also, upon the same Arch from C to D, set 6 deg. 2 min. the Distance of the Substile from the Meridian; and draw the Line A D for the Substilar.

Again, upon the same Arch set off 19 deg. 25 min. the Height of the Stile from D to E, and draw the Line A E for the Axis of the Stile.

A South Plain declining Eastward 30 deg. and reclining 55 deg. Pl. 6 Fig. 1.

Secondly, Upon any part of the Substilar Line, assume any point at pleasure, as F, through which draw the right Line G F H perpendicular to the Substile.

Thirdly, From the Point F, take the nearest Distance to the Axis of the Stile, and set that

E 5

Distance

Distance upon the Substilar Line from F to O, and upon the point O with 60 deg. of your Chord describe the Semicircle M L N.

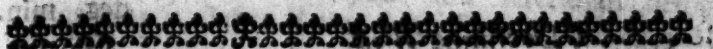
Fourthly, Lay a Ruler from O to K, (the point where the Tangent (or Equinoctial Line) crosseth the Meridian) and the Ruler will cut the Semicircle in L, at which point begin to divide it into 12 equal parts in the points $\odot \odot \odot$, &c.

Fifthly, Lay a Ruler from O the Center of the Semicircle to the several points $\odot \odot \odot$, in the Semicircle, and the Ruler will cut the Tangent Line in the points ***, &c.

Lastly, If from the Center A, through these points ***, &c. you draw right Lines, they shall be the proper Hour-lines belonging to your Plain.

For the Stile it may be either Plate or Wire, elevated above the Substile to an Angle of 19 deg. 25 min. and set up perpendicularly upon the Substilar, as in all other Dials. And thus have I done with all the Varieties of South Declining Reclining Plains.





II. Of North Recliners.

The First Variety.

CHAP. XXIII.

How to draw the Hour-lines upon a North Reclining Plain, Declining East or West, which cutteth the Meridian at the Intersection thereof with the Equinoctial.

LET the Example be of a North Plain Declining to the West 60 deg. and Reclining from the Zenith 32 deg. 11 min. in the Latitude of London, 51 deg. 32 min.

		d.	m.
Given	1. Latitude of the place	51	32
	2. Declination of the Plain } North West.	60	00
	3. Reclining North.	32	11

Required	1. The Distance of the Meridian and Horizon.
	2. The Height of the Pole or Stile above the Plain.
	3. The Distance of the Substile and the Meridian.
	4. The Plain's Difference of Longitude.

North

		deg.	min.
North	Declining West	60	00
	Reclining	32	11

First, Describe the Circle A H C O for the Declining Reclining Plain; cross it at right
Plate 6. Angles with the two Diameters H O
Fig. 2. for the Horizontal, and A C for the Vertical Line of the Plain.

AND here for Variety, more than for Necessity, in these three following Examples of *North Recliners Declining*, I will (in the several Schemes) place the Zenith and Pole downwards, because the Stile in all these Dials must point upwards, the North pole being always elevated; and in so doing, the Hour-lines, Stile, and Substile, will stand in the Scheme as they are to stand in the Dial; and the manner of the Work will be the same as before. Wherefore,

Secondly, Set 32 deg. 11 min. the Plain's Reclination, from O to *a*, and from C to B. A Ruler laid from H to *a*, shall give you the point *Æ*, through which, and the points H and O, the Horizon, H *Æ* O is to be described. And a Ruler laid from H to *b*, shall give you Z the Zenith point.

Thirdly, Set 60 deg. the Plain's Declination from A to *d*, a Ruler laid from Z the Zenith to *d*, shall cut the Horizon in S, the South point thereof. Thus have you two points Z and S, through which to draw the Meridian, whose Center will be in the Line Q E extended, and may be found as formerly is taught.

Fourthly,

Fourthly, The Horizon and Meridian being thus drawn, lay a Ruler from E to Z, and it will cut the *Plain* in e ; and seeing the Pole is 38 deg. 28 min. distant from the Zenith, set 38 deg. 28 min. from e to F, and a Ruler laid from E to F, will cut the Meridian in P the Pole of the World, through which point P, and the Center Q, draw the Line PQ for the Axis of the World, and *Substile* of the Dial. And again, because the Equinoctial is 90 deg. from the Pole, set 90 deg. from F, and they will reach just to Æ or a on either side, which are the very Points that the *Plain* cuts the Meridian in, and through which Points and the Point E, in the Horizon, the *Equinoctial Circle* must pass; whose Center will always be in the Axis of the World PQ extended.

THE *Horizon*, *Meridian*, and *Equinoctial*, being thus drawn, you may find the four Requisites in this manner.

1. To find the Distance of the Meridian from the Horizon Æ O . The Arch Æ O measured by your Line of Chords, will be found to contain 47 deg. 18 min. which is the *Substile's* Distance from the Meridian.
2. To find the Height of the Pole or *Stile* above the *Plain* P F. A Ruler laid from a to P, will cut the *Plain* in O; so the Distance F O on the Chords 42 deg. 52 min. is the Height of the Pole above the *Plain*.
3. The Distance of the *Substile* from the Meridian $a G$, which measured upon your Chord, will be found to contain just 90 deg.
4. The *Plain's* Difference of Longitude G P a , or the Arch $a G$, as before also 90 deg. just.

In this Scheme two Things are remarkable.

1. THE *Plain's* cutting the Meridian in its Intersection, with the Equinoctial. And,
2. THE *Axis* of the World passing through the East Point of the *Horizon*, both which denote the *Plain* to be polar Declining, and the *Subsile* to be the same with the Hour-line of 6. and the Hour-line of 12 at right Angles thereto, wherefore the Hour-lines may be drawn, as followeth.

To draw the Hour-lines upon the Plain.

First, Lay a Ruler from P to \mathcal{A} , where the Meridian and Equinoctial intersect, which is upon the *Plain* at the very Point \mathcal{A} , wherefore there begin to divide the Semicircle $\mathcal{A} G \mathcal{C}$, into 12 equal Parts at the Points $\odot \odot \odot$, &c.

Secondly, Lay a Ruler to Q, and every of the Points $\odot \odot \odot$, &c. and it will cut the Equinoctial in the Points * * *, &c. dividing that into 12 unequal parts.

Thirdly, A Ruler laid to P, and the several Points * * *, &c. in the Equinoctial, will cut the *Plain* in the Marks I I I, &c.

Lastly, A Ruler laid from Q to the several Marks, I I I, &c. and strait Lines drawn thereby, shall be the true Hour-lines fitting this polar Declining Plain.

For the *Stile*, it must be a Plate or Wire set upright upon the *Subsilar* to an Angle of 42 deg. 52 min. and must point upwards to the North-pole.

The



The Second Variety.

C H A P. XXIV.

How to draw the Hour-lines upon a North Reclining Plain, Declining East or West, the Plain passing through the Meridian, between the Zenith and the Equinoctial.

IN this, (as in the former Examples) three Things must be given, and four found, before the Hour-lines can be drawn.

		deg. m.
Given	1. Latitude of the Place	51 32
	2. The Declination of the Plain North W.	60 00
	3. The Plain's Reclination.	16 00

Required	1. The Distance of the Meridian from the Horizon.	
	2. The Height of the Pole or Stile above the Plain.	
	3. The Substile's Distance from the Meridian.	
	4. The Plain's Difference of Longitude.	

First, Describe the Circle *A H C O* for the Plain, and cross it with the Diameters *A C*, and *H O*, for the Horizontal and Vertical Lines thereof.

Second-

Secondly, (As in the last Example) set 16 deg. the *Plain's* Reclination, from

A North Dial O to *a*, and from C to *b*, a
Declining West 60 Ruler laid from H to *a*, shall
Reclining — 16 give the Point B, through
Plate 6. Fig. 3. which, and the Points H and
 O, the Horizontal Circle H
 B O is to be described. Also a Ruler laid from
 H to *b*, shall find the Zenith Point of Z.

Thirdly, Set the *Plain's* Declination 60 deg. from
 A to *d*, and from H to *e*: So a Ruler laid from
 Z to *d*, shall cut the Horizon in S the South, and
 laid from Z to *e*, shall cut it in E the East point
 thereof; and now having two Points Z and S,
 through them you may draw the Meridian Circle,
 as hath been already taught.

Fourthly, Lay a Ruler from E to Z, it will cut
 the *Plain* in F, and 38 deg. 28 min. the Comple-
 ment of the Latitude of the Place, set from F to
f, and a Ruler laid from E to *f*, will cut the Me-
 ridian in P the Pole of the World, and 90 deg.
 more, being set forward from *f* to *m*, and a Ru-
 ler laid from E to *m*, will cut the Meridian in Æ,
 the Equinoctial's Intersection with the Meridian;
 so have you two Points Æ and E, through which
 the *Equinoctial Circle* must pass, and a right Line
 drawn through P the Pole of the World, and Q
 the pole of the *Plain*, will be the Axis of the
 World, and the Substilar Line of the *Dial*.

THESE three Circles, viz. the *Horizon*, *Meri-
 dian*, and *Equinoctial*, being described, the fore-
 mentioned four Requisites may from thence be ea-
 sily obtained. For,

1. The Distance of the Meridian from the *Hori-
 zon*, is the Arch F H, 64 deg. 29 min

2. The

2. *The Height of the Pole or Stile above the Plain* P R. A Ruler laid from α to P, will cut the *Plain* in n : So the Distance R n measured, will be found to be 30 deg. 59 min.
3. *The Substile's Distance from the Meridian*, is the Arch I M, 64 deg. 26 min.
4. *The Plain's Difference of Longitude* is the Angle \angle P Q, which to find, lay a Ruler from P to \mathcal{A} ; and it will cut the *Plain* in D; the Distance D I measured upon the Line of Chords, will give 76 deg. 10 min. for the *Plain's Difference of Longitude*.

To draw the Hour-lines upon the Plain.

First, Lay a Ruler upon P the Pole of the World, and \mathcal{A} , the Intersection of the Meridian with the Horizon, and it will cut the *Plain* in D, at which Point begin to divide the Semicircle α I D into 12 equal parts, at the Points $\odot \odot \odot$, &c.

Secondly, Lay a Ruler from Q to the several Points $\odot \odot \odot$, &c. and it will divide the *Equinoctial Circle* into 12 unequal parts in the Points $***$, &c.

Thirdly, A Ruler laid from P to every of these unequal Parts $***$, &c. will cut the *Plain* in these Marks I I I, &c. dividing that into 12 other unequal parts.

Lastly, If you draw right Lines from Q, through every of these Marks I I I, &c. they shall be the true Hour-lines belonging to your *Plain*.

THE Stile may be either of Wire or Plate as in other *Dials*, and must be elevated above the *Substile*, to an Angle of 30 deg. 59 min. and must stand square, or at right Angles to the *Plain*.



The Third Variety.

C H A P. XXV.

How to draw the Hour-lines upon a North Reclining, or Inclining Plain, Declining East or West, which intersects the Meridian between the Equinoctial and the Horizon.

LE T this third and last Example of North Recliners Declining, be of a North Plain, reclining 54 deg. and declining Westward 60 deg. in the Latitude of London, 51 deg. 32 min.

THIS being the third and last Variety of declining reclining Plains, I shall be somewhat the larger in the Projection thereof, than I have been in any of the foregoing; not but that this Dial is to be made in all respects like (and with the same Ease) as the former. But herein I shall shew at large the Manner of Projection, and how all the Centers are Geometrically found, and the Reasons of their being in such and such Lines, and at such and such Distances. And also, I shall project all the Hour-lines belonging to the Plain upon the Plain it self by circular Lines, by which Means the Reader may attain to a more competent Knowledge in what hath been heretofore in this Treatise delivered. For from this Projection following, all the aforesaid hath been deduced. And therefore I shall describe the Manner of the delineating of this Dial, according to the following Proposition.

P R O-

PROPOSITION.

PLATE VII.

A Circle being described, representing a Declining Reclining Dial-plain; how thereon to place the Meridian, Horizon, Equinoctial, Pole, Zenith, &c. with all other Requisites belonging to such a Dial. And also, to project the Meridians of the Sphere itself upon the Plain, and from thence to draw the Hour-lines upon the Dial-plain, according to their true Situation.

LET the Circle $H S O B$, represent a Dial-plain in the Latitude of London $51^{\circ} 32'$ min. Declining from the North towards the West $60^{\circ} 00'$ min. and reclining from the Zenith Northward $54^{\circ} 30'$ min.

First, Cross the Circle with the two Diameters $H O$, and $S B$, cutting each other at right Angles in the Center Q . And because the Plain reclineth $54^{\circ} 30'$ min. take $54^{\circ} 30'$ min. out of your Line of Chords, and set that Distance upon your Plain from S to a , from O to b , and from B to c : Then lay a Ruler from H to a , and it will cut the Line $S B$ in Z , so shall the point Z be the Zenith of the Place.

Secondly, Lay a Ruler from H to b , it will cut the Line $S B$ in k , so shall k be a Point in the Line $S B$, through which the Horizon shall pass: And thus having three Points $H k O$, you may through them describe the Horizon, whose Center will

will be at m , the Distance $m k$ being equal to the Secant of the Complement of the Reclination of the *Plain*; namely 36 deg. — Or *Geometrically* thus, Draw the right Line $k O$, which divide into two equal parts in n , and upon the point n , raise a Perpendicular $n m$, extending it till it cut the Line $S B$ in m , so shall m be the Center of the *Horizontal Circle* $H k O$.

Thirdly, Lay a Ruler from H to e , it will cut the Line $S B$ (being extended) in the point N , so shall N be the Nadir-point.

Fourthly, Because the *Plain* declines 60 deg. from the North Westward; set 60 deg. from B to d , and laying a Ruler to Z the Zenith, (which is also the Pole of the Horizon) to d , it will cut the Horizon in S , through which Point the Meridian must pass.

Fifthly, Take (always) 90 deg. of your Line of Chords, and set that Distance from d to e , and laying a Ruler from Z to e , it will cut the Horizon in w the West-point thereof, and a Line drawn from w , through Q the Center of your *Plain*, will cut the Horizon (if you extend it as here is done) in E , the East-point thereof, and in some part of this Line (extended if need require) will the Center of the Meridian be; and where that Point will fall may be thus found.

Sixthly, Divide the Line $Z N$ into two equal parts in F , and upon F erect the Perpendicular $F D$, cutting the Line $Q w$ (extended) in D , so shall D be the Center of the Meridian of the Place.

Seventhly, If with your Compasses you take the Distance $D P$, and with that Extent upon D , as a Center, describe a Circle, you shall find that Circle exactly to pass through the respective points Z and N , if there be no former Error committed in your Work.

Eighthly,

Eighthly, Because the Height of the Pole above the Horizon, is equal to the Latitude of the place viz. at London 51 deg. 32 min. set off 51 deg. 32 min. upon the Meridian from S to P, in this Manner.

Ninthly, Lay a Ruler from *w*, the West-point of the Horizon, (which is also the Pole of the Meridian) to S, and it will cut the Plain in *b*; then set 51 deg. 32 min. from *b* to *f*. A Ruler laid from *w* to *f*, will cut the Meridian in P, so is P the pole of the World, distant from Z the Zenith, 38 deg. 28 min. and a Line drawn thro' P the pole of the World, and Q the Center of the Plain, will be the Axis of the World, and (extended) will cut the Meridian in M the South pole.

Tenthly, The Meridian and Horizon being thus drawn, it is easy to describe the Equinoctial; for if you consider the position of that Circle in the Sphere it self, you know that it always passes through the East and West-points of the Horizon, and cutteth the Meridian at right Angles; it being in all Places 90 deg. distant from either of the Poles. Wherefore, if upon *w*, (the Pole of the Meridian) you lay a Ruler to P the Pole of the World, it will cut the Plain in *f*; and if you set 90 deg. from *f* to *g*, and lay a Ruler from *w* to *g*, it will cut the Meridian in *Æ*; so have you three Points, through which the Equinoctial must pass, namely, E *Æ* and *w*, and the Center of the Equinoctial will be the Axis of the World, extended if Need require. To find which, you must,

Eleventhly, Divide the Line E *w*, into two equal parts in G, and from the point G, upon the Line E *w*, erect the Perpendicular G K, cutting the Axis of the World in K, so shall K be the Center

Center of the Equinoctial; wherefore, if upon K as a Center, with the Distance $K w$, you describe a Circle, that shall be the Equinoctial, and (if your Work be true) shall pass through the points E \mathcal{A} and w ; then for the dividing of the Equinoctial.

Twelfthly, Lay a Ruler to P the pole of the World (which is also the pole of the Equinoctial to \mathcal{A} , the Intersection of the Meridian and Equinoctial, and it will cut the *Plain* in the point 12 , at which point you must begin to divide the Circle representing your *Reclining Declining Plain* into 24 equal parts at the Points $\odot \odot \odot$, &c. This done, lay the Ruler to the point P , and every of the 24 equal Parts $\odot \odot \odot$, and you shall find it to cut the Equinoctial Circle in the points $***$, &c. dividing that Circle into 24 unequal parts, through which unequal parts, and the two Poles of the World P and M , must all the Hour Circles pass. For the describing whereof you must,

Thirteenthly, Divide the Line $P M$ into two equal parts in the Point L , (or, from the Point D , the Center of the Meridian, let fall a Perpendicular upon the Axis of the World, which will fall in the same Point L) and through the Point L , draw an infinite right Line at right Angles to $P M$, namely, the Line $C T$, for in that Line will the Centers of all the *Hour-lines* be found, and the Manner how to find them is thus (one way) to be effected.

Fourteenthly, Upon the point P as a Center, at the Distance $P L$, (or to any other Radius of a Line of Chords) describe the Semicircle $X L V$, and divide it into 12 equal parts at the Points \dots &c. beginning your Division at the Point J , which is, where the Ruler being laid from P , to D

D (the Center of the Meridian) cuts this last drawn Circle. Then laying a Ruler from P, upon each of these Divisions, you shall find it to cut the Line CT in the points 15, 30, 45, 60, &c. on either side of the Point D; and here note, that 15 is the Center of the first Hour's Distance from the Meridian on either Side thereof, 30 the Center of the second, and 45 of the third Hour's Distance from the Meridian, &c.

Fifteently, If you place one Foot of your Compasses upon 15, and extend the other to P the Pole of the World, and with that Distance describe a Circle, that Circle shall be the first Hour from the Meridian, and (if your Work be true) shall pass through M the South Pole, and also through $\phi\phi$, the two first unequal Divisions of the Equinoctial Circle, and so all the rest.

Lastly, If from Q the Center of your Plain, and the respective Points where the Hour-circles cut the Plain, you draw strait Lines, those shall be the true Hour-lines proper for such a Declination and Reclination, as you formed your Projection for.



Now

Now the Requisites belonging to this, and the like Declining Reclining Plains, are,

		d.	m.
1. The Height of the Pole above the Plain.	Represented by	P A	54 43
2. The Distance of the Meridian and Horizon.		H Y	53 31
3. The Distance of the Substile from the Meridian.		Γ A	56 41
4. The Angle between the two Meridians.		Æ P R	61 47

ALL which may be measured upon the Projection, and so their Quantities found: As,

1. To find P A, lay a Ruler from P to *w*, where the *Equinoctial* and the *Plain* do intersect, and the Ruler will cut the *Plain* on the other side at *x*; so A *x* measured upon the Line of Chords, will be 54 deg. 43 min. the Height of the *Pole* above the *Plain*, (or P Q measured upon a Line of half Tangents, will contain 55 deg. 17 min.) the Complement thereof.
2. To find H Y, the Arch H Y, measured upon the Line of Chords, will give 53 deg. 31 min. the Distance of the Meridian from the Horizon.
3. To find Γ A, the Arch Γ A measured upon the Line of Chords, will give 56 deg. 41 min. the Distance of the Substile from the Meridian.

4. To find Æ P Q , Lay a Ruler to P the Pole of the World, and Æ the Intersection of the Meridian and the Equinoctial, and it will cut the *Plain* in o , the Arch $o B$ measured upon the Line of Chords, will be found to contain 61 deg. 47 min. which is the Angle between the two Meridians.

THUS have you in this Scheme, delivered the true and genuine way of delineating Sun-Dials, deduced from the Sphere it self, by which the Reason of all that hath been before delivered, is rendered obvious, and sufficiently demonstrative for this place. But here you see, that the Centers of the Meridians or Hour-circles fall out to be very remote, and that there will be required a large Tangent-line for their Description, which will (for the most part) run out very far, and sometimes, almost to an infinite Excursion. I therefore chose rather to shew, how the Hour-lines might be drawn, without having any Regard to this Tangent-line, or without projecting of the Hour-lines upon the *Circular Plain*, and therefore the Ways before delivered are far more apt for practice than this, though this be more satisfactory to the inquisitive Reader, who will not be satisfied only with the doing, but of the understanding as well of what he does, and it is for the Satisfaction of such, that I have here added this Proposition.

F

CHAP.

C H A P. XXVII.

Concerning Inclining Plains, both Direct and Declining.

OF Reclining Plains there are but two Sorts, as hath been before instanced, and those are either *Direct* or *Declining*. The *Direct* are those *Reclining Plains* which do directly behold the *East*, *West*, *North* and *South* Points of the *Horizon*. And the *Declining* are those which (besides their Reclination from the *Zenith*) do respect two of the forementioned *Cardinal Points*, as,

(1.) The *South* and the *West*.

(2.) The *North* and the *West*.

(3.) The *South* and the *East*.

OR, (4.) The *North* and the *West*.

First	Sort are called	South declining	Reclining
Second		North West	
Third		South declining	
Fourth		North West	

Also before intimated; and gave Examples, that of *Direct Recliners*, there were three Sorts, viz.

1. SUCH as Reclining from the *Zenith*, do behold either the due *East*, or due *West* Points of the *Horizon*; and of this Sort there is only one kind, and no Variety in any Case. —

2. *South Recliners*, of which there are three Varieties. —

AND 3. *North Recliners*, of which also there are three Varieties. —

AGAIN,

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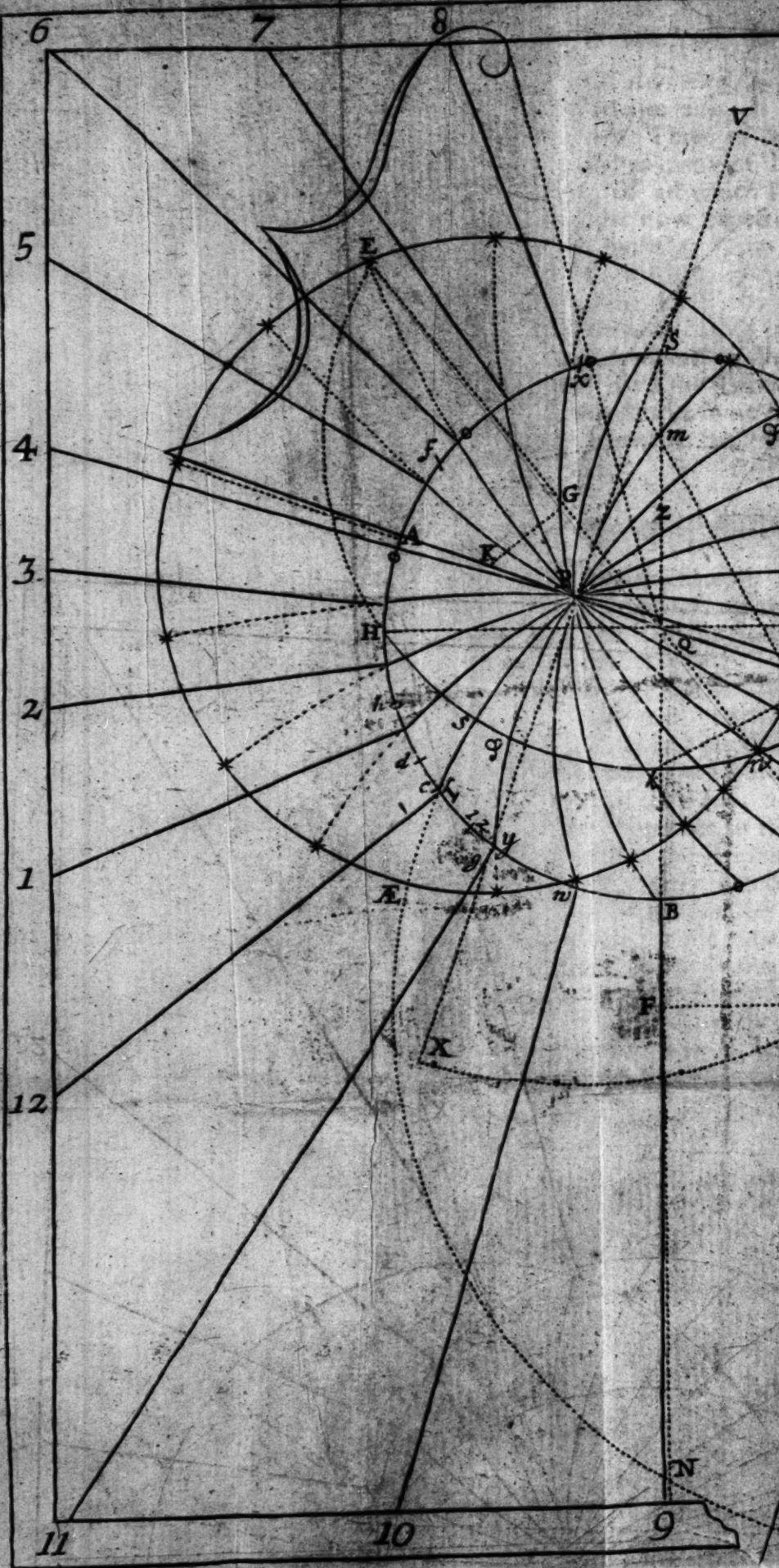
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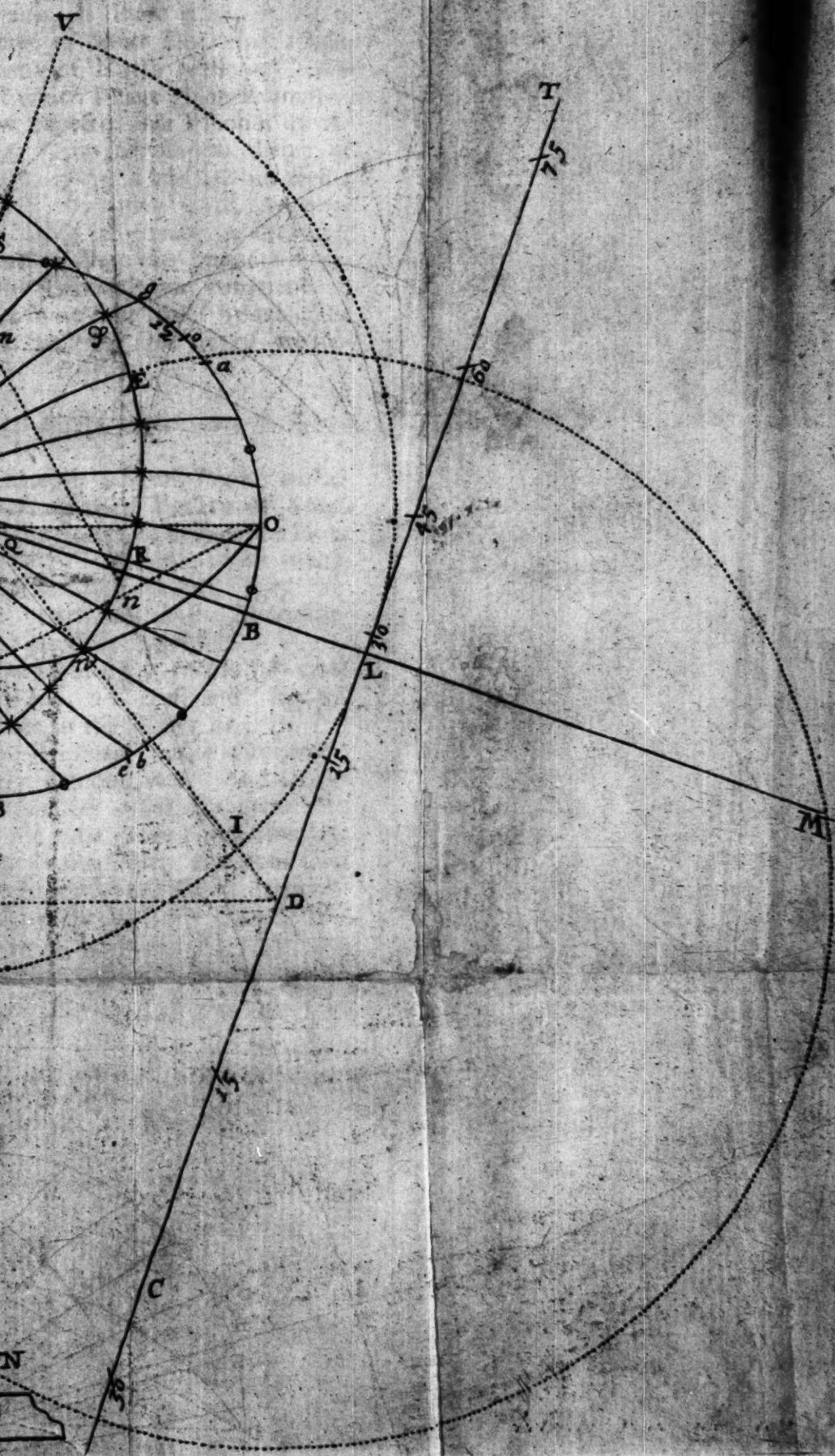
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IN,

AGAIN, Of *Reclining Declining*, I told you there were six Varieties also, as there were of *Direct Recliners*, viz. Three of *South Declining Plains* reclining, and as many of *North reclining Declining Plains*; of all which I have given Examples, and it may be now expected that I should do the like for the *Inclining Plains* opposite to them, of which there are also as many Varieties, but seeing that the making of the reclining *Dial*, whether *Direct* or *Declining*, doth also make the *Inclining Dial*, whether *Direct* or *Declining* opposite thereunto, I shall save the Labour, and commend to the Ingenious Reader some few Rules by which he shall easily frame the *Inclining Dial* out of the *Recliner*. And,

I. Of North and South Incliners.

I will take for Example a *South Plain*, reclining 55 deg. which is the third Variety of *South Recliners*, and I would from that deduce the Hour lines proper for a *North Plain* inclining as much, viz. 55 deg. And it is easily effected. For,

If you draw the Hour-lines of the *South Recliners* 6 A B 6, and the Stile thereof also, quite through the Center Q, to the opposite part of the *Plain*, 6 C D 6, and set the same Numbers to the Hours on the right Hand in the *Recliner*, and the contrary, as the Figure clearly demonstrates: And let the Axis in the *North Incliner* point downwards to the *South Pole*, as the Axis in the *South Recliner* doth upwards to the *North Pole*, and your *Dial* is finished. Or you may effect this Work by pricking off the Hour-lines through the Paper, and turning it upside down, and that will effect the same thing, only changing the Names of the Hours.

Or, again, if you turn the South reclining *Plain*, 6 A B 6 about, upon the Center Q, till the Line A B come to be in the place of C D, then will the Hours, Stile and all, be truly named and posited; and the very South Recliner will become the North Incliner without any Alteration.

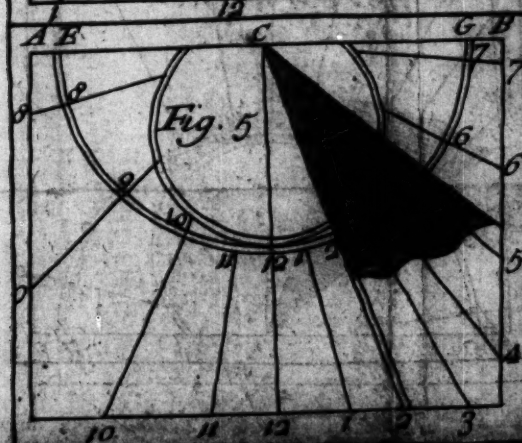
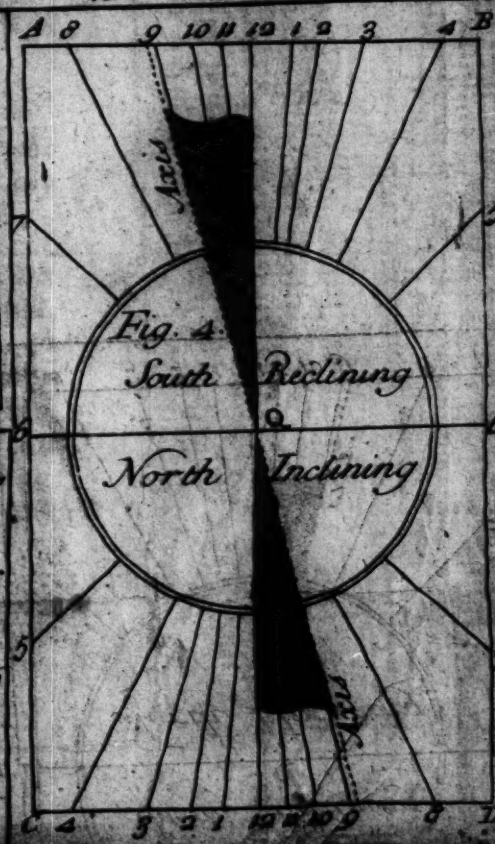
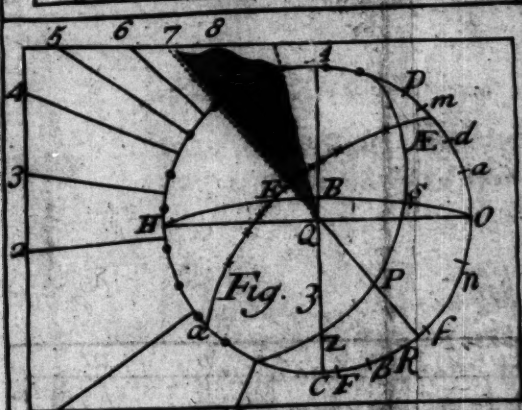
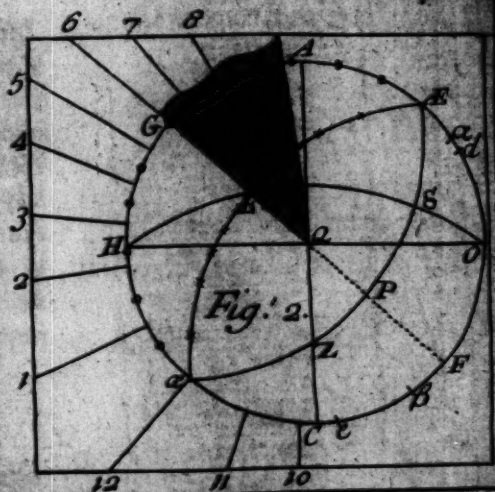
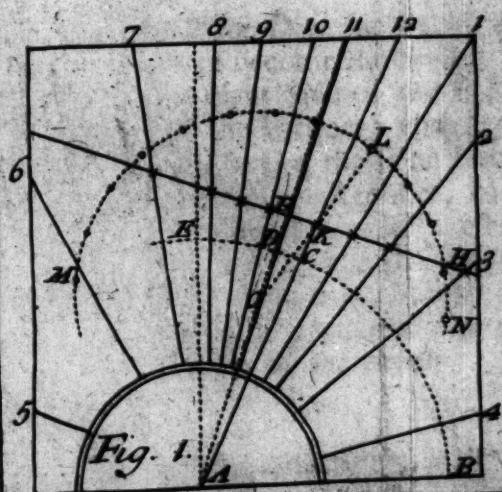
II. Of East and West Incliners.

THERE is little Difference in drawing of the *East* or *West* Inclining *Dials* from the reclining *Dials* opposite to them, from drawing the North Incliner before from the South Recliner. For,

In the Example of the *East* and *West* reclining and Inclining *Dial* before going, Chapter 10. The *Dial* as it there stands, represents an *East* or *West* reclining *Plain*. But if you turn the *Dial* about upon the Center Q, till the Letter N come to be in the place of the Letter S, in that Figure, then will the same *Dial* represent both an *East* and *West* *Dial* Inclining 35 deg. as now it doth an *East* or *West* reclining as much. The Substile, Stile, Meridian, and the rest of the Hour-lines retaining the same Names or Denominations, as now they do.

HI. Of North or South Declining Inclining Plains.

OF North and South reclining Declining Plains there were six Varieties, Examples of each have been largely given. There are as many of North and South Incliners, but seeing they may be so easily deduced out of their opposite Recliners, I shall forbear giving Examples, and the Way is not much differing from the Rules before given for Direct reclining and inclining Plains. For seeing the Reclination is alike proper to each, and the Deflection of the Substile from the Meridian in
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the Declinations do so directly agree, they may both be reduced to one and the same *Dial*, as the other were.

THUS, If any reclining *Dial* be so inverted, that the upper Part thereof become the nether, and after this Inversion the right Side of the Recliner become the left Side of the Incliner; and the contrary, the Inclining *Dial* having the same Declination, shall be framed out of the Recliner, and the contrary. Only the Denominations of the Hours must be changed. For the Fore-noon Hours in the Recliner, will be the After-noon Hours in the Incliner; and the Afternoon Hours of the upper *Dial*, the Forenoon Hours of the nether.



CH A P. XXVIII.

A General Rule to know which Pole, whether the North or the South, is to be elevated over any Plain.

THE Stile of every *Dial* respecteth (or rather lieth parallel with) the Axis of the World, and always pointeth upwards or downwards, to one of the Poles. Now when you have drawn your *Dial* (though truly) you may be to seek, whether it be the North or the South Pole that must be elevated; wherefore to avoid any Mistake, and to inform you which Pole is to be elevated, Observe this General Rule.

Upon all upright Plains, } South } side the } Pole.
 whether direct or de- } North }
 clining, upon the }

Upon all } Recliners } North } Pole.
 East and } the } South }
 West } Incliners }

Upon all } North Recliners } whether } North } Pole.
 } South Incliners } Direct or } South }
 } Declining }

South Re- } whe- } If the } Zenith } South } Pole.
 cliners } ther } Plain } and } North }
 } North In- } direct } Nadir } the } South }
 } cliners } or de- } between } Pole, }
 } } the } Horizon } the }
 } } } } ing. }

THIS Rule being duly observed, there will be no Difficulty to find which is elevated.

A Se-



A
Second Way
DIALLING,
Geometrically Performed.

PART II.

IN the foregoing First Part, you have a most absolute and perfect Way of delineating *Sun Dials* upon all sorts of *Plain Superficies* in what Position soever situate, and in any Latitude, whether the *Plains* be direct, or do decline, or whether they both decline and recline: And also you may there find, not only the manner how to make *Dials*, but to know the Grounds and

F 4

Reason

Reason of *Dials*, deduced from the Sphere or Globe projected in *plane*, upon the *Dial-plain's* Superficies.

BUT notwithstanding the Exactness and Rationality of delineating of *Hour-lines* upon all *Plains*, and in all Places, as is before taught; yet the ways there delivered, may (in some Cases, at some Times) be found inconvenient to put in Practice: As (1) When the Centers of some of the *Circles* fall out to be very remote. (2) When the unequal Divisions of the *Equinoctial Circle* come very near or close together, which they will always do, when the *Pole* hath but small Elevation above the *Plain*, and such like. For the removal of which Inconveniences, I shall in this Second Part add another *Geometrical Way of Dialling*, which shall be both plain, easie, exact, and quick of Dispatch; and all of it performed by strait Lines, and not by Circular Lines, as the former Way requires. And moreover, this second Way hath a Convenience, whereas most other *Geometrical Ways of Dialling* are liable to out-run the Limits of the *Plain*, by almost infinite Excursions: For in this Way, having first made a preparative Scheme upon Paper (or Pastboard rather) you shall have but very few Lines to draw upon the *Dial-plain* but the *Hour-lines* themselves.

In this Second Way, I shall be brief, beginning first to shew how to describe the *Hour-lines* upon *Upright Declining Plains*; referring the Delineation of Hours upon the *Horizontal full North, South, East, and West Plains* (whether upright or reclining) till afterwards: And the reason for my so doing, will of it self appear, when I shall come to treat of them. Wherefore to proceed.



SECTION I.

How to draw the Hour-lines upon an Upright South Plain declining from the South towards the West 20 deg. in the Latitude of London, 51 d. 32 m.

HA V I N G the Latitude of the Place, and the Declination of your *Plain* given, before you come to draw the Hour-lines upon the *Plain*, you must first draw your preparative Scheme as followeth.

I. *How to draw a Preparative Scheme suitable to any Declination in any Latitude. Pl. 8. Fig. 1.*

First, With 60 deg. or the Radius of your Scale of Chords, describe the Quadrant of a Circle A B D, extending the Side B A to C, so that A C be equal to A B: And then draw the Right Line D C.

Secondly, On the Point B, erect the Perpendicular B m.

Thirdly, Take 51 deg. 32 min. (the Latitude) out of your Line of Chords, and set them from B to F, and from D to G, and laying a Ruler from A to F and G, draw the two Lines F K, and G I.

Fourthly, From the point G, draw the Line G H, parallel to D A, or perpendicular to B A.

Fifthly, Take 20 deg. (the *Plain's* Declination) out of your Scale of Chords, and set them from D to E, and through the Point E, draw the Line E L, parallel to D A.

F. 5

Sixably,

Sixthly, With 60 deg. (or the Radius of your Scale of Chords) taken in your Compasses, set one Foot in the point D, and with the other describe the Arch A O, which divide into three equal parts in the points P and Q, for the whole Hours, each of which three Hour-spaces A P, P Q, and Q O, divide into four equal Parts at * * *, * * *, * * *, for Halfs and Quarters of Hours. Which done, if you lay a Ruler to the point D, and the points P and Q, the Ruler will cut the Line A C in the points 2 10, and 1 11, and by these points the Line A C is divided into three unequal parts in the Points 3, 9, 2, 10, 1, 11 and 12, representing four Hours. And if from D, you lay a Ruler over the several Spaces in the Hour-line A C into four unequal parts for Halfs and Quarters of Hours. And thus is your preparative Scheme so far finished. Wherefore now let us proceed,

II. To draw the Meridian, Stile, Substile and Hour-lines upon the Plain it self. Plate 8. Fig. 2.

First, Upon your *Dial-plain* draw a right Line as S T, for the Meridian, and Hour-line of 12. Upon which, assign any convenient point, as R, for the Center of your Dial; through which point R, draw the Line R W perpendicular to S T.

Secondly, Out of your preparative Scheme take the Line B K, and set it upon your *Dial-plain*, from R to T; also, from the preparative Scheme take B I, and set it on your *Dial-plain* from R to W, on the right Hand, because the *Plain* declineth West, and from T to V, make the rectangled *Parallelogram* R W V T on the East side.

Third-

Thirdly, Out of the preparative Scheme take the Line L A, and set it upon the *Dial-plane* from T to X, and from W to Θ , and draw the Lines R X for the Substilar Line, and R Θ for the Hour-line of Six, which draw quite through the Center R.

Fourthly, Out of your preparative Scheme, take the Line E L, and set it upon your *Dial-plane* from R to 12, and from X to Y, perpendicular to R X, and draw the Line R Y for the Axis (or Stile) of your Dial.

Fifthly, Out of your preparative Scheme, take the Line G H, and set it on your *Dial-plane* from R to Z, and draw the Line Z 6, parallel to W V, till it cut the Hour-line of Six in 6.

Sixthly, Make R 6 above the Center, equal to R 6 below the Center, and draw the two Lines 12 6, and 12 6.

Seventhly, Out of your *Dial-plane* take the Length of the Lines 12 6, and 12 6 severally, and set them upon the preparative Scheme from B to *b*, and from B to *a*. And laying a Ruler from C to *a* and *b*, draw the Lines M C, and N C.

Lastly, From the point A or 3, 9, take the nearest Distance to the Line N C, and set that Distance upon your *Dial-plane* from 12 to 9, for it will (if you work truly) divide the Line 6, 12 into two equal parts in 9. Also set one Foot of the Compasses in the point 2, 10 in the Line A C of the preparative Scheme, with the other take the nearest Distance to the Line N C, and set that Distance upon your *Dial-plane*, from 12 to 8, and from 6 to 10. — Again, setting one Foot of the Compasses in the point 1, 11. in the Line A C of the preparative Scheme, with the other take the nearest Distance to the Line N C, and set that Distance from 12 to 11, and from 6 to 7. So is

the longer Line 6, 12 on your Dial plain, divided into 6 unequal parts in the points 7, 8, 9, 10, and 11; through which points, Lines drawn from the Center R, shall be the true Forenoon Hours.

FOR the Afternoon Hours, the shorter Line 12, 6, on your Dial-plain, must be divided from the Line M C in the preparative Scheme, as the longer Line 12, 6 was before divided; by taking the least Distance from A or 9, 3 to the Line M C, and setting it from 12 to 3, or from 6 to 3. — Also the least Distance from 2, 10, to M C, in the preparative Scheme, will reach from 12 to 2, and from 6 to 4. — Likewise the least Distance taken from 1, 11, to the Line M C, in the preparative Scheme, will reach from 12 to 1, and from 6 to 5. So is the shorter Line 12 6, on the Dial-plain, divided into 6-unequal parts in the Points 1, 2, 3, 4, 5. Through which Points, and the Center R, right Lines being drawn, they shall be the true Hour-lines upon the Plain. And so is your Dial finished.

IF you would insert the Halfs and the Quarters of Hours into your Plain, you may easily do it, if from the preparative Scheme you take the nearest Distance from the Half and Quarter Points in the Line A C, and transfer them to the Lines 12, 6, and 12, 6, in the Dial-plate.





SECTION H.

How to describe the Hour-lines upon the Horizontal, full South, North, East and West, Erect or Reclining Plains. Plate 8. Fig. 3.

IN these kind of Plains, which directly behold the four Cardinal *North, South, East and West* Points, the Latitude of the Place, and Reclination of the *Plain* being known, there is nothing required, but to know the Elevation, or Height of the Pole above the *Plain*, which how to find, is sufficiently taught in the fourth and fifth Sections of the third Part of this Book : And therefore I shall not here mention the same again, but refer you to those fore-mentioned fourth and fifth Sections of the Third Part hereof. Wherefore, to draw Hours upon any of these *Erect, Direct, or Direct Reclining Plains*, when the Height of the Pole or *Stile* above the *Plain* is found, you have no more to do; but,

First, Draw a right Line *A B* for the Hour-line of Six, and another at right Angles thereto, for the Hour-line of 12, as the Line \odot *X*.

Secondly, With the Radius of your Line of Chords 60 deg. upon \odot as a Center describe the Semicircle *A X B*. And the Height of the Pole above the Plain being known, (as for an Horizontal Dial for *London*, where the Pole is elevated 51 deg. 32 min.) Take 51 deg. 32 min. from your Chord, and set them upon the Semicircle from *X* to *F*, and from *X* to *I*, and through the Points *F* and *I*, draw the Lines \odot *F* and \odot *I*, parallel to \odot *X*, and

X, and draw the Lines X 6 and X 6 on either side of the Meridian.

Thirdly, (Having Recourse to your former preparative Scheme) take in your Compasses the Length of the Line X 6, and set it upon the preparative Scheme from B to c, and laying a Ruler from C to c, draw the pricked Line C Δ.

Fourthly, In the preparative Scheme from the Point A or 9, 3, take the nearest Distance to the Line Δ C, and set it upon the Lines X 6, and X 6, from X to 3, and from X to 9. Also from the Point 2, 10, in the Line A C of the preparative Scheme, take the nearest Distance to the Line Δ C, and that Distance set upon the Lines X 6, and X 6, from X to 10 and 2, and from 6 to 8, and from 6 to 4. — Likewise, take the nearest Distance from the Point 1, 11, in the Line A C of the preparative Scheme, to the Line Δ C, which Distance will reach from X to 11, and from X to 1, and also from 6 to 5, and from 6 to 7. So are the two Lines X 6 and X 6 divided each of them into six unequal parts, the one in the Points 1, 2, 3, 4 and 5, and the other in the Points 11, 10, 9, 8 and 7. Through which Points, right Lines drawn from the Center ⊙, they shall be the true Hour-lines proper for an Horizontal Dial, for the Latitude of *London*, 51 deg. 32 min.

FOR the Stile of this Dial, a Line drawn from the Center ⊙, through either of the Points F and I, shall represent the Axis of the World, or Stile of the Dial.

For

For a Vertical or Erect South Dial for the same Latitude 51 deg. 32 min.

THE Height of the Pole above a South Plain in the Latitude of 51 deg. 32 min. is 38 deg. 28 min. the Complement of the Latitude. Wherefore,

First, Take 38 deg. 28 min. from your Scale of Chords, and set them from X to G, and from X to H, and draw the Lines G M and H L parallel to \odot X. Draw also X M and X L.

Secondly, Take the Length of the Line X M and X L, and apply it to your preparative Scheme, setting it from B to d, and laying a Ruler from C to d, draw another pricked Line C d.

Thirdly, The nearest Distances taken from the Points A 2, 10, and 1, 11, in the Line A C of the preparative Scheme, will (being transferred from thence to the *Dial-plane*) divide the Lines X M and X L, each of them into six unequal parts, through which Divisions, and the Center \odot , Lines being drawn, they shall be the true Hour-lines of an *Erect South Dial* in the Latitude of London.

A Line drawn from \odot (the Center of the Dial) through the Points H or G, shall represent the Axis of the World, and be the *Stile* of this Dial.

For a Direct North Reclining Plain.

LET your Example be of a *Direct North Plain Reclining from the Zenith 25 deg.* and such a Dial is described in the 17th Chapter of the First Part, and the Height of the Pole or Stile above the Plain, was there found to be 63 deg. 28 min. And

And so it will be found to be by the Rule delivered in the Fifth Section of the Third Part of this Book.

First, The Height of the Stile being found to be 63 deg. 28 min. take 63 deg. 28 min. from the Scale of Chords, and set them from X to E, and from X to K, and draw the Lines E C and K D, parallel to the Meridian \odot X. Also draw the Lines X C, and X D.

Secondly, Take the Length of the Line X C on from X D, and set it upon the preparative Scheme from B to *e*, and draw a third pricked Line as *e* C.

Thirdly, The nearest Distances taken from the Points A 2, 10, and 11, 12, in the Line A C, shall, (being set upon the Lines X C and X D) divide them each into six unequal parts, through which and the Center \odot , right Lines being drawn, they shall be the true Hour-lines of a North Direct Plain Reclining 25 deg. in the Latitude of London.

THE Stile must be drawn from the Center \odot , through the Point E or K.

For Direct East or West Plains, whether Erect or Reclining.

FOR Erect Direct Plains, where the Hour-lines are parallel one to another, the Stile or Pole having no Elevation, the best Way to make them, is, as is directed in the sixth Chapter of the First Part. And therefore in this Place, nothing more need be said concerning them. But,

Let your Example be of a Direct North Plain Reclining from the Zenith 25 deg. and from a Dial placed in the 17th Chapter of the First Part, and the Height of the Pole or Stile above the Plain was there found to be 63 deg. 28 min. And

For East and West Recliners.

THE best Way to deal with these kind of *Plains*, is to refer them to a new Latitude, and to a new Declination in that new Latitude, both which are easily attained by this following GENERAL RULE.

1. *The new Latitude, is always the Complement of the old Latitude.*
2. *The new Declination in that new Latitude is the Complement of the Reclination.*

So that if a direct East Plain, in the Latitude of *London* 51 deg. 32 min. should recline 40 deg. and you would find the new Latitude, and new Declination ;

First, The Complement of the old Latitude 51 deg. 32 min. is 38 deg. 28 min. And that must be the new Latitude.

Secondly, The Reclination being 40 deg. The Complement thereof is 50 deg. And that is the new Declination.

So that if (by the Direction of the first Section hereof) you make an Erect Dial to decline 50 d. in the Latitude of 38 deg. 28 min. that Dial shall serve for an *East* or *West Dial*, reclining 40 deg. in the Latitude of 51 deg. 32 min.

Thirdly, Although this Declining Plain be truly made, yet the placing of it upon the *Dial-plain* differeth from *Erect Plains* : For, in all Erect Declining Plains, the Hour-line of 12 is always perpendicular to the Horizontal Line of the Plain. So in all *East* and *West* reclining Plains, the Hour-line of 12 must lie parallel to the Horizontal Line of the Plain. As you may see in the *Figure* Chap. 10, of Part the First.

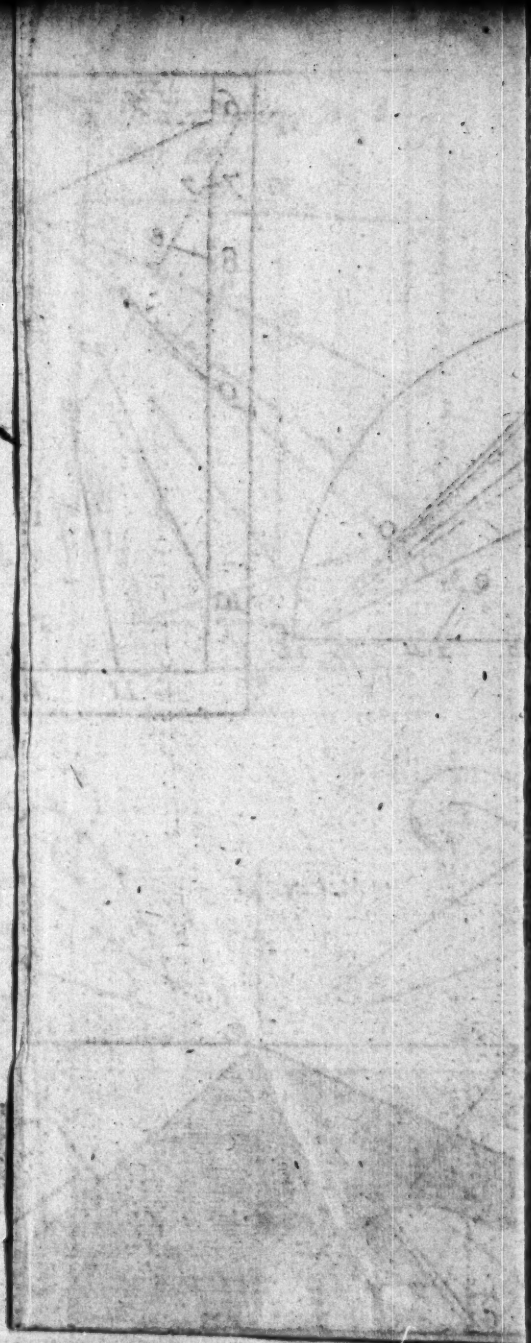
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It may here be expected, that I should say something concerning *Declining Reclining Plains*, which this Geometrical Way will very well perform by referring them to a new Latitude and a new Declination, where they will become *Erect Declining Plains*; but there are three Ways in this Book already taught, how to effect the same by other Means. I thought good to omit them in this Place; and to give Examples in *Erect Direct*, in *Direct Reclining*, and in *Erect Declining Plains* (as being of all others the most useful.) And so I shall conclude this *Second Geometrical Way of Dialling*.

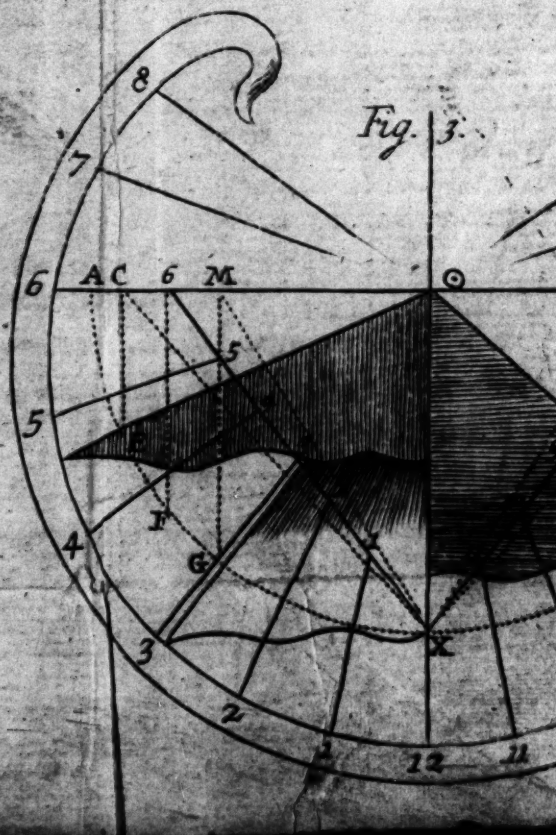


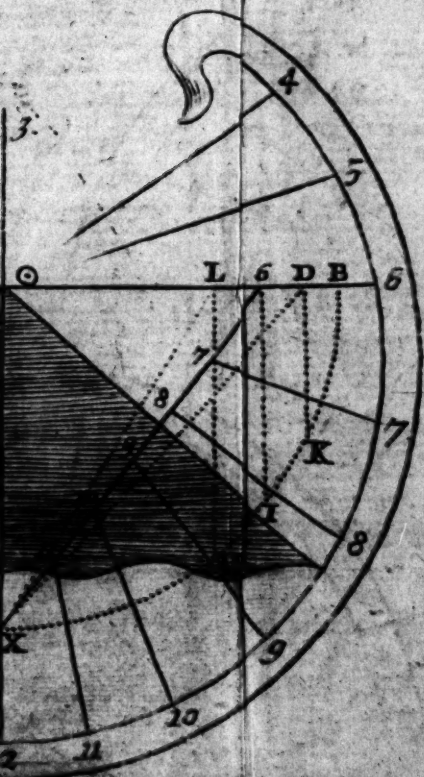
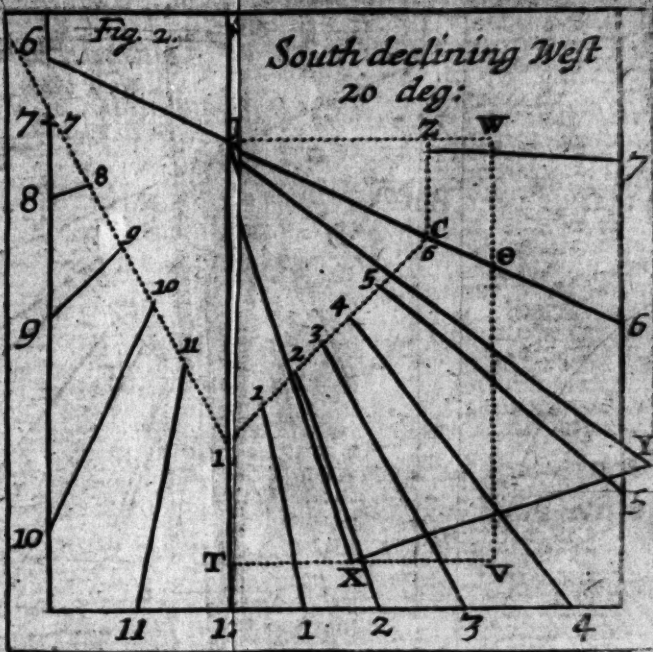
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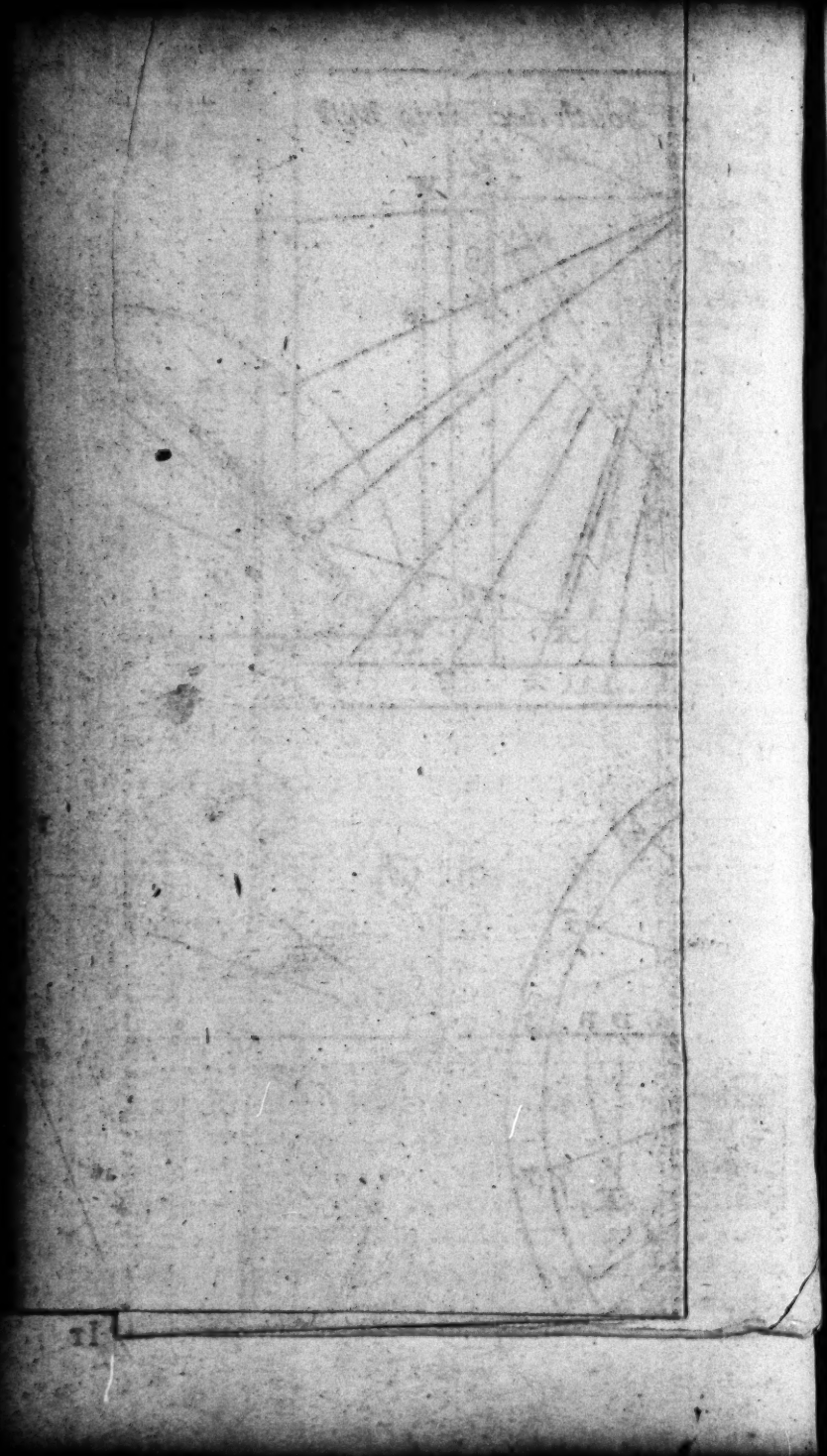
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The A R T of
D I A L L I N G,

Arithmetically Performed.
By the **CANONS** (or **TABLES**)
of Artificial *Sines* and *Tangents*.

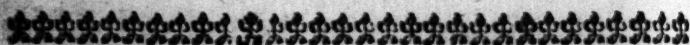
P A R T III.

The Argument.



HEREAS the two foregoing *Geometrical* Ways, of delineating or making of *Sun-Dials*, may be rejected by some, and a more accurate Performance of the same required by others, I thought good, (to make this Treatise the more compleat, which for a *Geometrical* Way is already perfect enough) to add the Canons, Analogies, or
Propor-

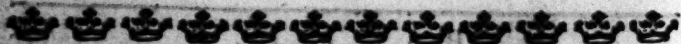
Proportions; by which the several Requisites in all Plains may be *Arithmetically* attained, by the Help of the Canons or Tables of Artificial Sines and Tangents (than by which there can be no exacter Way.) Which Tables are already in most Mens Hands, and the general Use of them no less common: Wherefore I shall say nothing of that in this Place, but proceed to the finding the Forementioned Requisites, as followeth. And,



SECTION I.

Of Vertical or Horizontal Plains.

IN these Plains there is nothing required but the Height of the Pole above the Plain, which in all Places is equal to the Latitude of the Place, for which the Dial is to be made.



SECTION II.

Of North and South Erect Direct Plains.

IN these Plains also there is nothing required but the Height of the Pole above the Plain, which in all Places is equal to the Complement of the Latitude of the Place. Wherefore, subtract the Latitude of the Place, for which your Dial is to be made from 90 deg. and the Remainder

mainder is the Height of the Pole above the South or North Erect Direct Plain.

	deg.	min.
From	90	00
Subtract Latitude	51	32
There remains	38	28

Which is the Height of the Pole above a Direct North or South Plain in the Latitude of 51 deg. 32 min.



SECTION III.

Of North and South Erect Declining Plains.

BUT in Erect Declining Plains, (besides the Latitude of the Place, and the Declination of the Plain) there are three Things requisite to be found, before you draw the Dial, and they are,

1. *The Height of the Stile (or Pole) above the Plain.*
2. *The Distance of the Substile from the Meridian.*
3. *The Plain's Difference of Longitude.*

1. *Example, In the declining Plain in Chapter 8. whose Declination was 24 deg. 20 min. in the Latitude of 51 deg. 32 min.*

1. For

1. *For the Height of the Pole above the Plain.*

As the Radius 90 deg. 10.000000

Is to the Co-sine of the Latitude } 9.793831
 38 deg. 28 min.

So is the Co-sine of the Declinati- } 9.959596
 on 65 deg. 40 min.

To the Sine of 34 deg. 33 min. 9.753427

Which 34 deg. 33 min. is the Height of the Pole above the Plain.

2. *For the Distance of the Substile from the Meridian.*

As the Sine of 90 10.000000

Is to the Sine of the Plain's De- } 9.614944
 clination 24 d. 20 m.

So is the Co-Tangent of the Lat- } 9.900086
 tude 38 d. 28 m.

To the Tangent of 18 d. 8 m. 9.515030

Which 18 deg. 8 min. is the Distance of the Substile from the Meridian.

3. *For the Plain's Difference of Longitude.*

As the Co-sine of the Latitude 38 d. } 9.793832
 28 min.

Is to the Radius 90 deg. 10.000000

So is the Sine of the Distance of } 9.493080
 the Substile from the Meridian
 18 deg. 8 min.

To the Sine of 30 deg. 01 min. 9.699148

Which 30 deg. 01 min. is the Plain's Difference of Longitude.

S E C-



SECTION IV.

Of South Direct Reclining Plains.

IN these *Plains*, (the Latitude of the Place, and the Reclination of the Plain being given) there is only required the Height of the *Pole* above the *Plain*: In which there are three Cases, in all which you may find the *Stile's* Height, as followeth:

1. IF the Reclination of the *Plain* be less than the Complement of the Latitude of the Place, subtract the Reclination out of the Complement of the Latitude, and the Remainder will be the Height of the *Pole* or *Stile* above the Reclining *Plain*. But,
2. IF the Reclination of the *Plain* be more than the Complement of the Latitude, subtract the Complement of the Latitude from the Reclination, and the Remainder shall be the Elevation of the *Pole* above the *Plain*.
3. IF the Reclination be equal to the Complement of the Latitude, the *Pole* hath no Elevation over such a *Plain*, but is an *Equinoctial Plain*, and must be made by the Rules delivered in the twelfth Chapter of the First Part of this Book.

1. Case

			deg. m.
	Latitude 51 deg. 32 min.	}	
	Complement		38 28
1. Case	Reclination		22 10
			<hr/>
	Height of the Pole above the Plain.	}	16 18
	Reclination		62 23
	Latitude 51 deg. 32 min.	}	
	Complement		38 28
2. Case			<hr/>
	Height of the Pole above the Plain.	}	23 55



SECTION V.

Of North Direct Reclining Plains.

IN these *Plains* also (the Latitude and Reclination being given) there is only required the Height of the *Pole* above the *Plain*.

To find this,

1. Add the Complement of the Latitude to the Reclination, and the Sum of them is the Height of the *Pole* above the *Reclining Plain*.

	deg. min.
Lat 51 deg. 32 min. Compl.	38 28
Reclination	27 12
	<hr/>
Height of the Pole above the Plain.	65 40

2. But

2. BUT if this Sum exceed 90 deg. then subtract it from 180 deg. and the Remainder shall be the Height of the *Pole* above the *Plain*.

	deg.	min.
Latitude 51 deg. 32 min. Compl.	38	28
Reclination.	70	42

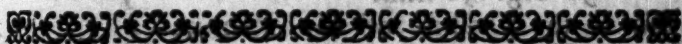
Sum. 109 10

Which subtract from 180 00

There remains 70 50

WHICH 70 deg. 50 min. is the Height of the *Pole* above the *Plain*.

3. IF the Sum of the Complement of the Latitude and the Reclination added together do make just 90 deg. then that *Plain* is a *Polar-plain*, and the Dial for such a *Plain* must be made in all Respects as is directed in the 16th Chapter of the first Part of this Book.



SECTION VI.

Of East and West Direct Reclining Plains.

IN East and West reclining Plains (the Latitude of the Place, and Reclination being given) there are required the same three Things as in North and South Erect Decliners, namely,

1. *The Height of the Pole (or Stile) above the Plain.*
2. *The Distance of the Substile from the Meridian.*
3. *The Plain's Difference of Longitude.*

Example, Of the East or West reclining Plain, Part I. Chap. 10. whose Reclination was 35 d. 00 m. and Latitude 51 deg. 32 min.

G

1. For

1. *For the Height of the Pole or Style above the Plain.*

As the Radius 90 deg.

10.00000

Is to the Sine of the Latitude 51 d. 32 min. } 9.89374

So is the Sine of the Reclination 35 d. 9.75859

To the Sine of 26 deg. 41 min. 9.65233

Which 26 deg. 41 min. is the Height of the Pole above the reclining Plain.

2. *For the Distance of the Substile from the Meridian.*

As the Radius 90 deg.

10.00000

Is to the Tangent of the Latitude 51 deg. 32 min. } 10.09991

So is the Co-sine of the Reclination 35 deg. } 9.91336

To the Tangent of 45 deg. 52 min. 10.01327

Which 45 deg. 52 min. is the Substile's Distance from the Meridian.

3. *For the Plain's Difference of Longitude.*

As the Sine of the Latitude 51 d. 32 m. 9.89373

Is to the Radius 90 deg. 10.00000

So is the Sine of the Substile's Distance from the Meridian 45 deg. 52 min. } 9.85595

To the Sine of 66 deg. 27 min. 9.96211

Which 66 deg. 27 min. is the Plain's Difference of Longitude.

SECTION VII.

Of South and North Declining Reclining Plains.

IN Declining Plains reclining (besides the Latitude of the Place, Declination and Reclination of the *Plain*; (which are for the most part given) there must four Things be found before you can draw the Dial, *viz.*

1. *The Distance of the Meridian and Horizon.*
2. *The Height of the Pole or Style.*
3. *The Distance of the Substile from the Meridian.*
4. *The Plain's Difference of Longitude.*

OF these Plains you have in the 20, 21, 22, 23, 24, and 25 Chapters of the first Part, six Varieties, which are all that in any Case may happen, *viz.* Three of South Declining Reclining, and as many of North Declining reclining; I shall only instance in two of them, *viz.* one of a South reclining Plain Declining Easterly, and another of a North reclining Plain Declining Westerly. The Example of the South Recliner shall be that in the third and last Variety of South Decliners reclining, and that is of a South Plain declining Easterly 30 deg. and reclining 55 deg. as in Part I. Chap. 22.

I. In South Decliners Reclining.

1. For the Distance of the Meridian from the Horizon.

As the Radius 90 deg. 10.00000

Is to the Sine of the Reclination 9.91336
 55 deg. }

So is the Tangent of the Declination 9.76144
 30 deg. }

To the Tangent of 25 deg. 19 min. 9.67480

Which 25 deg. 19 min. being taken from 90 deg. leaves 64 deg. 41 min. the Distance of the Meridian from the Horizon.

2. For the Height of the Pole (or Stile) above the Plain.

This will require two Operations.

1. As the Radius 90 deg. 10.00000

Is to the Sine of the Distance of 9.95615
 the Meridian from the Horizon }
 64 deg. 41 min. }

So is the Co-sine of the Reclination 9.75859
 55 deg. }

To the Sine of 31 deg. 14 min. 9.71474

Which 31 deg. 14 min. being less than the Latitude 51 deg. 32 min. subtract it therefrom, and there will remain 20 d. 18 m.

Then

Then again say,

2. As the Sine of the Distance
of the Meridian from the Ho- } Co. Ar. 0.04385
rizon 64 deg. 41.

Is to the Sine of the Arch last } 9.54025
found 20 d. 18 m.

So is the Co-sine of the Declination } 9.93753
30 deg.

To the Sine of 19 deg. 25 min. 9.52163

WHICH 19 deg. 25 min. is the Height of the
Pole or Stile above the Plain.

Note, That if the Arch found at the first of
these Operations be equal to the Latitude of
the Place (as there it was lesser, viz. but 31
deg. 14 min.) then the reclining Plain had
been an Equinoctial Decliner, and must be
made as by the Precepts delivered in the 20th
Chap. of the first Part.

3. For the Distance of the Substile from the Me-
ridian.

As the Co-Tangent of the Declina- } 9.76144
tion 30 d. Co. Ar.

Is to the Sine first found in the last } 9.71477
Proportion, viz. 31 d. 14 m.

So is the Tangent of the Height of } 9.54714
the Pole above the Plain 19 deg.
25 min.

To the Sine of 6 deg. 3 min. 9.023348

G 3

WHICH

WHICH 6 deg. 3 min. is the Distance of the Substile from the Meridian.

4. For the Plain's Difference of Longitude.

As the Sine of the Difference of the Arch first found, and the Latitude of the Place, viz. 20 d. 18 m. } 9.54025

Is to the Radius 90 deg. } 10.00000

So is the Sine of the Substile's Distance from the Meridian 6 d. 3 min. } 9.02335

To the Sine of 17 deg. 44 min. } 9.48310

WHICH 17 deg. 44 min. is the Plain's Difference of Longitude.

II. In North Decliners Reclining.

IN all these Plains (as well as in South Recliners) four Things must be found (besides the Latitude of the Place, and the Reclination of the Plain, which are commonly given) before the Dial can be drawn; and those are the same as in South Recliners, viz.

1. The Distance of the Meridian from the Horizon.

2. The Height of the Pole (or Style) above the Plain,

3. The Distance of the Substile from the Meridian.

4. The Plain's Difference of Longitude.

ALL these may be found by the following Canons or Analogies. And for an Example, I shall make use of the North Plain declining Westerly

Westerly 60 deg. and reclining 34 deg. as
in the last Example of North Recliners,
Part I. Chap. 25.

1. *For the Distance of the Meridian from
the Horizon.*

As the Radius 90 deg.

10.00000

Is to the Sine of the Reclination 34 d. 9.90795
So is the Tangent of the Declination } 10.23856
60 deg.

To the Tangent of 54 deg. } 10.14651
29 min.

WHICH 54 deg. 29 min. being taken from 90
deg. leave 35 deg. 31 min. And that is the
Distance of the Meridian from the Horizon.

2. *For the Height of the Pole (or Style) above
the Plain.*

THIS also will require two Operations.

1. As the Sine of the Declination 60 d. 9.93753

Is to the Radius 90 deg.

10.00000

So is the Co-sine of the Distance of
the Meridian from the Horizon 35 } 9.91059
deg. 31 min.

To the Sine of 70 deg. 2 min. 9.97306

To this Sine of 70 deg. 2 min. add the Com-
plement of the Latitude 38 deg. 28 min. the
Sum will be 108 deg. 30 min. and this Arch
(being above 90 deg.) take it from 180 deg.
so there will remain 71 deg. 30 min.

G. 4.

2. As

2. As the Sine of the Arch first }
 found 70 deg. 2 min. } Co. Ar. 0.02694

Is to the Sine of the Reclination }
 54 deg. 0 min. } 9.90796
 So is the Sine of the Arch last found }
 71 deg. 30 min. } 9.97695

To the Sine of 54 deg. 43 min. 9.91185
 WHICH 54 d. 43 m. is the Height of the Pole
 or Stile above the Plain.

Note, That if the Arch first found, viz. 70 d.
 2 m. had been just 90 d. the Plain then had
 been a polar declining Plain, the Substile and
 the Hour of six being the same, and must
 be made by the Precepts delivered in Part I.
 Chapter 23.

3. For the Distance of the Substile and Meridian.

As the Tangent of the Reclina- }
 tion 54 deg. } Co. Ar. 9.86126

Is to the Sine of the Arch first }
 found, viz. 54 d. 29 m. } 9.91059
 So is the Tangent of the Height of }
 the Pole above the Plain 54 deg. } 10.15021
 43 min. }

To the Sine of 56 deg. 42 min. 9.92206
 WHICH 56 deg. 42 m. or rather the Complement
 thereof to 180 d. viz. 123 d. 18 m. is the
 Distance of the Substile from the Meridian,
 according as you please to account it, either
 from the North, or from the South.

4. For

4. *For the Plain's Difference of Longitude.*

As the Sine of the Height of the Pole }
above the Plain 54 d. 43 m. } 9.91184

Is to the Tangent of the Distance }
of the Substile and Meridian } 10.18251
56 d. 43 m.

So is the Radius 90 deg. 10.00000

To the Tangent of 61 d. 48 m. 10.27067

WHICH 61 deg. 48 min. is the Plain's Difference of Longitude counted from the North, or the Complement thereof 10 180 deg. viz. 118 d. 12 m. is the same Difference of Longitude counted from the South.



SECTION VIII.

Of the Hour Distances upon the Plain.

HITHERTO you have in a general, plain and easy Method, (and of all others the most exact) delivered the Manner how to calculate the Requisites belonging to all sorts of Plains, whether *Direct*, *Reclining*, *Declining*, or both. It resteth now, to find the true Hour-Distances one from another upon any of these Plains, and for that (for all Dials which have Centers) there is only one general Analogy or Proportion, and that is this, Having found the Plain's Difference of Longitude; say,

As the Radius or Sine of 90 deg.

Is to the Sine or Height of the Pole or Stile
above the Plain.

So is the Tangent of each Hour's Distance (upon the Equinoctial) from the Substile.

To the Tangent of the same Hour's Distance
upon the Plain counted from the Substile.

Now, (because Examples do more confirm than barely Precepts) I shall by Precedent or Example make plain all that hitherto hath been delivered, and one shall serve instead of many, and that shall be in an upright or erect declining Plain, (which of all Dials are the most common and useful.) Suppose therefore,

In Latitude 52 deg. 40 min. an erect Plain beholding the South, to decline Westward 24 deg.

The Arithmetical Calculation.

By the Rules delivered in the third Section of these Precepts, you shall find,

1. *The Height of the Pole (or Stile) above the Plain to be 33 deg. 38 min.*
2. *The Distance of the Substile from the Meridian to be 17 deg. 14 min. And,*
3. *The Plain's Difference of Longitude to be 29 deg. 15 min.*

THESE Requisites being thus attained, the next Thing is to find the Hour Distances upon the Plain, which may be done by the last foregoing Analogy.

But

But first, you are to consider the Quantity of the Plain's Difference of Longitude, which here in this Example, is found to be 29 deg. 15 min. And because every Hour's Distance upon the Equinoctial is 15 deg. distance from the Substile, or Meridian of the Plain; so 2 Hours is 30 deg. Distance, and 3 Hours is 45 deg. Distance: This Plain's Difference of Longitude being above 15 d. (which is one Hour's Distance) and less than 30 deg. (which is two Hours Distance) the Substile (the Plain declining Westerly) must needs fall between the Hours of 1 and 2 in the Afternoon. Wherefore subtract 15 deg. (1 Hour's Distance) from 29 deg. 15 min. and there will remain 14 d. 15 min. the Equinoctial Distance of 1 a Clock from the Substile. Also from 30 deg. (which is two Hour's Distance) subtract 29 deg. 15 min. and the Remainder will be 00 deg. 45 min. for the Equinoctial Distance of 2 a Clock from the Substile. Having found the two Equinoctial Distances of the two next Hour-lines, on either side of the Substile (as of 1 and 2) the rest are easily found by the continual Addition of 15 deg. and so is the Column of the Equinoctial Distances in the following Table made. Being thus prepared, the true Hour-distances from the Substile upon the Plain, may be easily attained by the foregoing Analogy. I will instance in one Hour's Distance: for all, and give you the rest in a Table: As,

Let it be required to find the Distance of one a Clock upon the Plain from the Substile, say,

15	00	15	V
30	15	30	IV
45	30	45	III

As

As the Sine of 90 deg. 10.00000

Is to the Sine of the Height of the } 9.74341
 Style 33 deg. 38 min. }

So is the Tangent of the Equinoctial } 9.40478
 Dist. of 1 a Clock, viz. 14 d. 15 m. }

To the Tangent of 8 d. 0 min. 9.14819

Which 8 d. 0 m. is the Distance of the 1 a Clock

Hour-line upon the Plain from the Substile. And

in the same manner you may find the Distance

of 2 a Clock to be 0 d. 25 m. Of 3 a Clock

8 d. 53 m. Of 4 a Clock 18 d. 14 m. and so

the rest, as in the following Table for every

whole Hour. And if you desire halves and quarters

of Hours, you must insert them in the Column

of Equinoctial Distances, allowing 7 d. 30 m.

for half an Hour, and 3 d. 45 m. for a quarter,

and so 15 d. for a whole Hour.

Hours	Equinoctial Distances		True Hour Distances	
	deg.	min.	deg.	min.
VIII	89	15	88	39
IX	74	15	63	1
X	59	15	42	57
XI	44	15	28	21
XII	29	15	17	14
I	14	15	8	0
Substil.				
II	0	45	0	25
III	15	45	8	53
IV	30	45	18	14
V	45	45	29	37
VI	60	45	44	41
VII	75	45	65	22

Thus

THUS have you the Arithmetical Calculation of the whole Dial; it now remains to shew how these Hour-lines are to be transferred from the Table to the Dial-plain, which is to be done as followeth.

The Geometrical Projection.

First, (Upon your Dial-plain) draw an Horizontal-line A B, and perpendicular thereunto another Line C D, for the Meridian and Hour line of 12.

Secondly, Take 60 deg. out of your Line of Chords, and setting one Foot in C, with the other describe the Semicircle E F G.

Thirdly, Because the Distance of the Substile from the Meridian was found to be 17 deg. 14 min. Take 17 deg. 14 min. from your Line of Chords, and set them upon the Semicircle from F to H, and draw the Line C H for the Substile.

*South Declining
West 24 d. Lat. 52
deg. 40 min. Plate
6. Fig. 5.*

Fourthly, The Height of the Stile being 33 d. 38 m. set that Distance upon the Semicircle from H to K, and draw the Line C K for the Stile.

Fifthly, (Having Recourse to your Table) take 18 deg. 39 min. out of your Line of Chords, and set them upon the Semicircle from H to 8, and draw the Line C 8 for the Hour-line of 8 of the Clock.

Lastly,

for the Hour-lines.



and
draw
the
lines

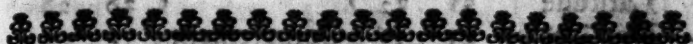


deg. min. 1 57 21 14 0 25 59 14 37 41 22
63 42 18 17 8 0 8 18 29 44 65
and set the
same upon
the Semi-
circle up-
on the
Plain from
H, to

Lastly from
your Line of
Chords, take

Thus is your Dial finished, only the Stile, which must be set to hang perpendicularly over the Sub-
stile, making an Angle at the Center of the Plain.
33 d. 38 m. equal to the Height of the Stile.

And thus have you an Abstract of the whole
Art of Dialling, after the most exact and com-
pendious Way of Performance ; others may be
more expeditious, but none more exact.



SECTION IX.

IT will be to little Purpose to be thus curious in finding of the true Positions of the Meridian, Stile, Substile and Hour-distances in all Plains, as in the foregoing Precepts is delivered, unless also we be as severe or strict in finding of the Site or Position of the *Plain*, upon which the Dial is to be made. For what will it signify to make the Dial true, and place it in a wrong Position? You are in the Geometrical Part of this Book taught how to find the Declination of any *Plain*, and for the finding of it, to attain the true Azimuth of the Sun is the chief Ingredient, and how to perform that Geometrically, is there taught two Ways. But that the like Exactness may be in the Performance of this also, I shall in this Place (before I end) exhibit the manner of finding the Sun's Azimuth at any Time, and in any Place by Arithmetical Calculation.

Example. In the Latitude of 51 deg. 38 min. the Sun having 17 deg. 56 min. of North Declination, and his Altitude 35 deg. Let it be required to find his Azimuth.

First, Add the Complement of the Latitude, the Complement of the Declination, and the Complement of the Sun's Altitude all into one Sum, and take the half thereof, from which half Sum subtract the Complement of the Declination, and note the Difference as here is done.

2.

deg.

	deg.	min.		deg.	min.
Latitude	51	32	Complement	38	28
Declination	17	56		72	04
Altitude	35	00		55	00

Sum 165 32

Half Sum 82 46

The Difference between the half Sum
and the Compl. of the Declination. } 10. 42

Then will the Proportion be.

(1.) As the Radius 90 deg. } 10.00000

Is to the Co-sine of the Altitude } 9.91336

So is the Co-sine of the Latitude } 9.79383

To the Sine of 30 deg. 38 min. } 9.70719

(2.) As the Sine of 30 deg. 38 min. } 9.70719

Is to the Sine of the half Sum } 9.99653

So is the Sine of the Difference } 9.26873

To this Sine } 19.26526

To which add the Radius or Sine } 9.55807

of 90 deg. } 10.00000

The Sum is } 19.55807

The half Sum } 9.77903

Which

Which is the Sine of 36 deg. 38 min. the Complement whereof is 53 deg. 2 min. and that doubled is 106 deg. 4 min. which is the Sun's Azimuth from the North Part of the Meridian, which if you take from 180 deg. there will remain 73 deg. 56 min. which is the Azimuth from the South. And thus may you find the Sun's Azimuth more exactly at any Time: Or more expeditiously thus,

OPERATION.

	deg.	min.		deg.	min.
Co-Alt.	55	00	Co-decli.	72	04
Co-Lat.	38	28			
Difference	16	32	Half	36	02
Half	08	16	$\frac{1}{2} +$ and $-$	08	16
			Sum	44	18
			Diff.	27	46

	deg.	min.		
Sine	55	00	Co-Ar.	0.086636
Sine	38	28	Co-Ar.	0.206168
Sine	44	18		9.844114
Sine	27	46		9.668266

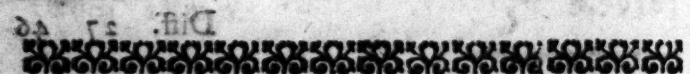
Sum 19.805184
9.902592

Half is Sine 53 d. 2 m.

Doubled is 106 d. 4 m. the Sun's Azimuth from the North, as before.



A
SUPPLEMENT
TO
Geometrical DIALLING, &c.



CH A. P. I.
Of such Circles of the Sphere, as are described upon Sun-dials.

MANY Astronomical Conclusions may be performed by describing the Circles of the Sphere upon the Dial-plates; of which I have here made Choice of these following:

1. THE Parallels of the Signs, shewing what part of the Zodiack the Sun is in at all Times of the Year.

2. THE

2. The *Diurnal Arches*, shewing the Length of the Day and Night throughout the Year.

3. The Hours from the Sun's Rising, or Setting; or the *Babylonish* or *Italian Hours*.

4. The *Unequal, Jewish, or Planetary Hours*.

5. The *Azimuths*, or *Vertical Circles*, shewing in what Quarter of the World, or upon what Point of the *Mariner's Compass*, the Sun is at all Times of the Day.

6. The *Almicanter*, or *Circles of Altitude*; whereby the Proportion of Shadows to their Objects, or the Sun's Height may be known.

Of these some are great Circles of the Sphere, others small: The great Circles in all Plains are represented by strait Lines, as the Hour-lines themselves are: The lesser Circles are described by Conick Sections; and they are either *Parabolas*, *Hyperbolas*, or *Ellipses*: Only the *Parallels* of the Signs, and the *Diurnal Arches* in *Polar Dials*, and the *Parallels* of Altitude in *Horizontal Dials*, are perfect Circles.



How to describe the *Aequinoctial*, the two *Tropicks*, and other intermediate *Parallels* of Declination, upon any Dial-plain.

THE two *Tropicks* being the Boundaries of the Sun's Course, (for he never exceeds those Limits,) I count it best, first to shew how they may be described; for that between them all other Circles (either great or small) must be pro-

projected, and the manner of describing them upon several *Plains* is various.

IN a *Polar Dial* they are perfect Circles, and so are easily described by Circles drawn about the Foot of the *perpendicular Stile*; in all other *Plains* they are Sections of a *Cone*.

I. *In the Equinoctial and direct East or West Dials. Plate 9.*

LET an Example be of a direct East Dial, in the Latitude of 51 d. 32 m.

How to describe the Hour-lines upon these *Plains*, is shewed in the 6th Chapter of this Book. Wherefore such a Dial being drawn as in Figure I, through the Foot of the *Perpendicular Stile* at E, draw a right Line M, E, N, parallel to the Horizon; for the Horizontal Line in all *Plains* must be drawn through the Foot of the *Perpendicular Stile*, and also through the Point where the *Equinoctial Circle* crosseth the Hour-line of Six. Your *Dial*, with the Equinoctial Line thereof H, E, S, being drawn, come we to describe the *Tropicks*: To effect which,

First, Upon a Piece of fine Card-Past-board, draw a right Line O R, as in Figure II. representing the Equinoctial Lines in your Dial; and (because the *Tropicks* are 23 deg. 30 min. distant from the Equinoctial) with 60 deg. of your Chords, upon the Point O, describe an Arch of a Circle, and upon it set 23 deg. 30 min. from R to S, and draw the Line O S, representing the two *Tropicks*; and this Angle S, O, R, I call a *Trigon*.

Secondly, Out of your Dial take the Length of the *Perpendicular Stile* E G, and set it upon the

Trigon from O to P, and draw the Line P 6 perpendicular to O R: Also,

Take the Distance from G, to the Intersection of the Hour-line of

7 } with the Equi- } and } Perpen-
 8 } noctial, and set } draw } dicular
 9 } them upon the } the } to O R.
 10 } Trigon from O } line }
 11 } to } VII }

HAVING thus prepared the Trigon, out of it take the Distance P 6, and set it upon the 6 a Clock Hour-line from E to c: — Also take the Distance q 7, and set it upon your Plain from V to b, and from VII to d: — Also take r s, and set it on your Plain from IV to a, and from VIII to e: — Likewise take the Distance s 9, and set it upon your Plain from IX to f: — Also take the Distance 10 z, and set it from X to g: Lastly, take v 11, and set it on the Plain from XI to b.

THESE Points a, b, c, d, e, f, g, h, are the Points through which the Tropick of Cancer must be described; wherefore, if through them a Line be drawn with an even Hand, making no Angles, that shall be the Tropick of Cancer.

THE Tropick of Capricorn may be described in the same manner, if for your Trigon you take

The Distance } 8 r } And set it up- } VIII }
 } 9 s } on your Dial } IX }
 } 10 z } Plain from } X } to }
 } 11 v } } XI } }

Those shall be the Points through which the Tropick of Capricorn must be described; wherefore if through

through *k l m n*, a Line be drawn with an even Hand, it shall represent the Tropick of *Capricorn*.

AND whereas I said before, that the two Tropicks are the Boundaries of the Sun's Course, you are to note, That

When the Sun is in

<i>Capricorn</i> ,	} which is about	<i>Dec. 11.</i>	} the Shadow of the	
<i>Aries</i> ,		<i>Mar. 10.</i>		top of the <i>Stile</i> will
<i>Libra</i> ,		<i>Seps. 12.</i>		pass along those re-
<i>Cancer</i> ,		<i>June 11.</i>		spective Lines.

AND according to this Method may any other intermediate Parallels of Declination be inserted; as for Example, Suppose I would insert the Parallels of the Sun's Entrance into the 12. Signs, *Aries* and *Libra* are inserted already, also *Cancer* and *Capricorn*; for the rest, as when the Sun enters into

<i>Taurus</i> ,	} the Sun hath 11	} of Declination.	
<i>Virgo</i> ,			deg. 30 min.
<i>Scorpio</i> ,			
<i>Pisces</i> ,			
<i>Gemini</i> ,	} the Sun hath	}	
<i>Leo</i> ,			20 deg. 12 min.
<i>Sagittarius</i> ,			
<i>Aquarius</i> .			

WHEREFORE take 11 deg. 30 min. and 20 deg. 12 min. out of your Line of Chords, and set them upon the Arch *R S* of your Trigon, from *R* to *V* and *X*, and draw the two Lines *O U* and *O X*.

THESE

THESE *Parallels* being thus put into your *Trigon*, they may be transferred into the *Dial-plain*, in all respects, as the *Tropicks* were; and as you see done in the *Figure I.*

II. In a direct North or South Dial. Plate 9. Fig. 3.

HAVING drawn your Dial, as is taught in Chapter V. together with the *Stile*, your first Work must be to proportion your *Stile* to your *Plain*; which to do, assume any convenient Point in the *Substile* (here the *Line of XII.*) for the farthestmost *Tropick*, as here the Point \odot ; then the *Stile's* Height being 38 deg. 28 min. add 23 deg. 30 m. thereto, the Sum is 61 d. 38 m. and that is the *Meridian Altitude* of the Sun when he enters *Cancer*, and the Complement thereof 28 deg. 2 m. wherefore, upon the Point *Cancer*, make an Angle BOA to contain 28 deg. 2 min. so shall the Line $\odot\text{A}$ cut the Axis of the *Stile* OA , in A ; then from A let fall a perpendicular to \odot , as AB ; and so is your *Stile* proportioned to your *Plain*; and the Line CBD , (being drawn parallel to the *Horizon*, through the Point B) shall be the *Horizontal-line* of the *Plain*.

THIS done, prepare a *Trigon*, as *Figure IV*, in which make EF equal to OB , and EG , to AB , the Triangle EFG in the *Trigon*, equal to the Triangle of the *Stile* OAB in the *Dial*.

FROM the Point E draw a perpendicular to EF , as E12 , for the *Equinoctial*; and upon E , with 60 deg. of your *Chord* describe an Arch H12L , and upon it set 23 deg. 30 min. from 12 to H and L , drawing the Line EH for the *Tropick* of *Cancer*, and EL for the *Tropick* of *Capricorn*.

DRAW

DRAW the *Substilar* Line F G quite through the Trigon, crossing the Equinoctial in *a*, and both the Tropicks.

THIS done, out of your Trigon take the Distance from F to *a*, and set it upon the *Dial-plain* from the Center O to *e*, through which Point *e* draw the right Line γe for the Equinoctial: Then from O, the Center of your Dial, take the Distance to the Intersection of the *Hour-line* of 11 or 1 with the Equinoctial, and set that Distance upon the Trigon from F to *b*: — Also take the Distance from O, to the Intersection of the *Hour-line* of 10 or 2, and set it from F to *c*: — Likewise the Distance from O, to the Intersection of the *Hour-line* of 9 or 3, set from F to *d*: — And lastly, the Distance from O to the Intersection of 8 or 4, with the Equinoctial, set from F to *e*; and draw the Lines F *a*, F *b*, F *c*, F *d*, F *e*, through the Trigon, marking them with 12, 11, 10, 9, 8, and 1, 2, 3, 4, &c.

Now to find the Points upon the Plain, thro' which the Tropicks must pass;

The Distance from F to

12	} will reach	{	from O,	{	on the	{	12	}	
11							from O,		11
10							the Center		10
9							of the Dial		9
8							to		8

Through which Points the Tropick of Cancer, must be drawn with an even Hand, And,

The

The Distance from F to

12	{	will reach	{	w k l m v	{	12	12	
1		from O, the				upon the	11	1
2		Center of				Hour-lines	10	2
3		the Dial,				of	9	3
4		to			8	4		

Through which Points the Tropick of *Capricorn* must be drawn. And thus have you the *Equinoctial*, and the two *Tropicks* described upon a direct South Plain.

III. How to describe the *Equinoctial*, and the two *Tropicks* into any upright declining Plain ; or into such as both Recline and Decline.

OUR Example shall be in an Upright Plain, declining from the South Westward 30 deg. The making of these Dials is taught in the 7th and 8th Chapters of this Book : Wherefore, having drawn such a *Dial*, with the *Stile* and *Substile* in a due Position, you shall find the Height of the *Stile* to be 32 deg. 36 min.

First, Make an *Horizontal Dial* for the Latitude of 32 deg. 36 min. as in the *Declining Dial*, Fig. 5. where the *Substilar-line* is taken for the *Hour-line* of 12, as it is there marked, and the other pricked Lines, and the *Hour-lines* of an *Horizontal Dial* for the Latitude of 32 deg. 36 min. Now if according to the Directions of the foregoing Section, you make a *Trigon*, and insert the *Equinoctial* and *Tropicks* ; and afterwards expunge the obscure Lines of the *Horizontal Dial*, the *Equinoctial*, *Tropicks*, and *Horizontal Line* will be the same, as if they had been inserted from the *Hour-lines* belonging to the Plain.

H

AND

AND as the *Tropicks* were described, so likewise may the *Parallels* of the Sun's Entrance into the other Signs, be inserted, if into your Trigon you put the Arches of their Declinations from the Equinoctial, namely, 11 deg. 30 min. and 20 deg. 12 min. And so are the *Parallels* of the Signs put into this Dial, Plate 10. Fig 5.

AND in any Dial also may the *Diurnal Arches* be described, if you put into the Trigon such Declinations, as the Sun hath from the Equinoctial, when the Day is either

		deg. min.			
$\left. \begin{array}{c} 8 \\ 9 \\ 10 \\ 11 \\ 12 \end{array} \right\}$	or	$\left. \begin{array}{c} 16 \\ 15 \\ 14 \\ 13 \\ 12 \end{array} \right\}$	Hours long, as	23	30
				21	40
				16	55
				11	37
				5	55
				00	00

And so are the *Diurnal Arches* put into the South Plain, represented by the pricked Lines there, in Fig. 3. and the Trigon thereunto belonging. Fig. 4. both in Plate 9.



CHAP. III.

How the Hour-lines from the Sun's Rising and Setting are to be inscribed into all sorts of Dial-planes.

THE Hour-lines from Sun-rising are called the *Babylonish Hours*, for that they begin their Day at the Sun's Rising; and the Hours from Sun

Sun-setting are called the *Italian Hours*, for that they count their Time from the Setting of the Sun the Day preceding.

THE Manner how to inscribe these Hours, is the same in all *Plains*, and is easily performed: And because that upon a full *South*, or *Horizontal Plain*, they will appear most uniform; I have therefore made Choice of a direct South Dial, as is Fig. 3. Plate 9. to inscribe them:

YOUR *Dial* being drawn, and the *Equinoctial* γ γ , and the two *Tropicks* \mathcal{E} \mathcal{E} , and ν ν , and the *Horizontal Line*, *Sun rise*, *Sun set*; you must (by the last Chapter) describe two obscure Parallels of Declination, one when the Day is 8 Hours long, as \odot 8 \odot , and the other when the Day is 16 Hours long, as * 16 *: The *Equinoctial* being the Parallel when the Day is 12 Hours long.

BEING thus far prepared, the Inscription of these Hours will be very easie; for it is plain, that when the Day is but 8 Hours long, the Sun rises at 8 in the Morning; and the first Line after the Sun's Rising is 9 in the Morning: — Also when the Day is 12 Hours long, the Sun rises at 6 in the Morning, and the first Hour after is 7 in the Morning; — Lastly, When the Day is 16 Hours long, the Sun rises at 4 in the Morning, and the next Hour after is 5 in the Morning: — And all the rest as in the following Table.



	Length of the Day.		
	VIII	XII	XVI
I	9	7	5
II	10	8	6
III	11	9	7
IV	12	10	8
V	1	11	9
VI	2	12	10
VII	3	1	11
VIII	4	2	12
IX	5	3	1
X	6	4	2
XI	7	5	3

WHEREFORE a strait Line drawn through the Intersections of these Hour-lines, with the Parallels of 8, 12, and 16 Hours, shall be the first Hour after the Sun-rising all the Year long.

In like manner, if you would insert the 7th Hour after the *Sun-Rising*: By the Table you see that in the *Parallel* of VIII Hours for the Length of the Day, the seventh Hour from Sun-rising is 3 in the Afternoon; therefore observe where the Hour-line of 3 crosseth the *Parallel* of VIII Hours, which is at *a*. — Also by the Table you see that in the *Parallel* of XII Hours, for the Length of the Day, the seventh Hour from *Sun-rising* is 1 in the Afternoon; wherefore observe where the Hour-line of 1 crosseth the *Equinoctial*, which is at *b*. — Thirdly, By the Table you see, that in the *Parallel* of XVI Hours for the Length of the Day, the seventh Hour from the Sun's rising is 11 in the Forenoon; and therefore observe where the Hour-line of XI crosseth the *Parallel* of XVI Hours for the Length of the Day, which is at *c*; so shall a right

right Line, drawn through these three Points *a*, *b*, *c*, be the seventh Hour after the Sun's Rising throughout the Year: And thus by the Help of this little Table, may all the Hour-lines from the Sun's Rising be drawn as you see them drawn and numbred, as in *Fig. 3. Plate 9.*

IN the same Manner, as the Hours from the Sun's Rising (which are the *Babylonish* Hours) were drawn, may the Hours from the Sun's setting, (which are the *Italian* Hours) be drawn: The Difference being only in numbering of them; the Hours from Sun rising being numbered from the West End of the *Horizontal Line*, by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10: And the Hours from Sun setting from the East End of the *Horizontal-line* backwards, by 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13; all which is evident in the fore-named *Fig. 3.*

C O R O L L A R Y.

THE Hour-lines from Sun rising and Sun setting being described upon any *Dial-plain*, as is before taught; there will by their correspondent Intersections one with another, be points produced, through which if Lines be drawn with an even Hand, the same shall be the Parallels of the Length of the Day, and such are the pricked Lines in *Fig. 3*, numbred upon the Meridian-line of the Dial, by 8, 9, 10, 11, 12, 13, 14, 15, 16.



C H A P. IV.

Of the Jewish, or Old Unequal, or Planetary-hours, and how they may be inscribed upon any Dial-plain.

TH E Ancients Account of their Day, was from the Sun's Rising in the Morning, till its setting in the Evening, which Space of Time they did divide into 12 equal Parts, were it long or short: So that in the Summer all that Time that the Sun hath North Declination, the *Hours* of their Day were longer than a common equal *Hour*; and in the Winter, when the Sun hath South Declination, the *Hours* of their Day were shorter than a common *Hour*; but when the Sun is in the *Equinoctial*, their *Hours* are equal to our common *Hours*.

THE Inscription of these *Hour-lines* into all sorts of Plains, is very easy, being much like the Inscription of the *Italian* and *Babylonish* Hours, taught in the last Chapter.

HAVING

The Jewish Hours.	The Parallel of 15 Hours.		Equinoctial.	The Parallel of 9 Hours.	
	ho.	min.		Ho.	Min.
I	5	45	7	8	15
II	7	0	8	9	0
III	8	15	9	9	45
IV	9	30	10	10	30
V	10	45	11	11	15
VI	12	0	12	12	0
VII	1	15	1	0	45
VIII	2	30	2	1	30
IX	3	45	3	2	15
X	5	0	4	3	0
XI	6	15	5	3	45
XII	7	30	6	4	30

HAVING drawn your Dial with *Hours, Halfs,* and *Quarters*; and also the *Equinoctial*, the two *Tropicks* and *Horizontal Line*; and also the *Parallels* of the Length of the Day, as is done in *Fig. 6. Plate 10.* which is a South Dial declining Eastward 15 deg. you must make Choice of two *Parallels* of the Length of the Day, which must both of them be equidistant from the Equinoctial, which let be the *Parallels* of 9 Hours, and 15 Hours, for those two *Parallels* are most convenient for this Purpose; because the *Jewish Hours* in those *Parallels* will justly fall upon the even *Hours, Halfs,* or *Quarters*: Now the Points thro' which the *Jewish Hours* are to be drawn, this Table will direct to; wherein you see, that the first *Jewish Hour* is to be drawn through 5 Hours, 45 min. in the Parallel of 15 Hours, through 7 in the Equinoctial, and through 8 Hours and 15 min. the Pa-

H 4.

rallel

rallel of 9 *Hours*. — In like manner the second *Jewish Hour* must be drawn through the Intersection of the 7 *Hours* in the Parallel of 15 *Hours*, through 8 in the Equinoctial, and through 9 in the Parallel of 9 *Hours*: And so must all the rest of them be described as the Table does direct, and as you see done in *Fig. 5*. And in this Manner, by help of this Table, may they be described in all sorts of *Plains*, whether Direct, Reclining or Declining.



CHAP. V.



How the Azimuths or Vertical Circles are to be inscribed upon Dial-plains.

THE Azimuths are great Circles, and being projected upon all Plains, become strait Lines; and they are variously described, according as the *Plain* is situated. Particulars of which follow:



SECTION I.

On an Horizontal Plain.

IN these Plains the Azimuths are most easily inserted: For, your Dial being drawn, with the *Tropicks* and *Equinoctial* thereupon, you have no more to do, than upon the Foot of the Perpendicular Stile at O (in *Fig. 7*.) as a Center, to describe a Circle, as S  N , which you may divide

divide into 32 equal Points (beginning at N) answering to the 32 Points of the *Mariner's Compass*, (or else you may divide it into 90 equal Parts or Degrees) noted with * * *, &c. and thro' those Points draw strait Lines from O, the Foot of the perpendicular Stile, and they shall be the true Azimuths upon the *Horizontal Plain*; which you may denominate by *South*, S by E, S S E, S E by S, &c. as you see done in *Fig. 7. Plate 10.*

SECTION II.

Upon an Erect, Direct East or West Plain,
Plate 9. Figure 1.

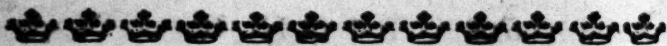
HAVING made an East Dial, and therein inserted the Equinoctial, the two Tropicks, and the *Horizontal-line*, you may proceed to the Inscription of the Azimuths in the manner following.

UPON the Point E, of the *Horizontal-line* of the Plain M, E, N, erect the Perpendicular E Q, equal to E G, (the Height of the Stile of your Dial) and upon Q, as a Center, describe the Quadrant Q E L, and divide it into 8 equal Parts, representing one Quarter of the *Mariner's Compass*, and from Q, through those Points, draw Lines to the *Horizontal-line* M, E, N, noting them with ☉ ☉ ☉ ☉ ☉; from which Points let fall Perpendiculars from the *Horizontal-line*, and they shall be the Azimuths between the South and the East:— And for those Points which fall between the East and the North; namely, E by N, — E N E, — N E by N, — the same Distances being set

H. 5

upon:

upon the *Horizontal Line* from E, towards the left Hand, as the three first Azimuths, E by S, — *E S E*, — *S E* by E, were towards the Right Hand, shall give the three Points ☉ ☉ ☉ on the Left Hand of E; through which Points also Lines drawn perpendicular to the Horizon, shall be the Azimuth or Points of the Compass between the East and the North: As in Fig. 1. And as the East Dial contains the Azimuths between the South and the East: The West Dial must contain those between the South and the West.



SECTION III.

Upon a Direct South upright Plain. Plate 9. Fig. 3.

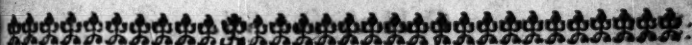
THE Dial, with the Equinoctial, the two Tropicks, and the Horizontal Line described thereon, the Azimuth may be inserted thereon as followeth:

First, Take the Length of the perpendicular Stile of your Dial A B, and set it upon the Meridian of your Dial from B to G.

Secondly, With the Distance G B, upon G describe the Semicircle E B F, which divide into 16 equal Parts, (if you will) but I have here divided it but into 8, to shew the manner of the Work, in the Points * * * *, &c. through which Points from G, draw obscure Lines, extending them till they touch the Horizontal Line of the Plain C B D; now if from these Points of touching, you draw Lines perpendicular to the Horizontal-line between the Tropicks, or parallel to the Line of *az*, they shall be the Azimuths required.

I have

I have not drawn the Lines themselves in this Fig. 3. because the Plain is full enough of Lines already.



SECTION IV.

Upon a South Declining Plain. Plate 10. Fig. 6.

AN Example shall be of a South Plain, declining Eastward 15 deg.

SUCH a Dial being drawn, and the *Equinoctial Tropicks*, and the *Horizontal Line* inscribed thereon: Upon the Point B of the *Horizontal Line* erect the Perpendicular BC, equal to BO, the perpendicular Stile of your Dial; upon which point C describe the Semicircle RBS; which done, lay a Ruler to C, and the point ☉, where the Hour-line of 12 crosseth the *Horizontal Line*, and where the Ruler cuts the Semicircle RBS, at that Point begin to divide it into 16 equal parts, at the Points *** , &c. and from the Center C draw Lines through these Points, extending them till they touch the *Horizontal Line* DE in the Points *a b c d e f g h i k* and *l*; through these Points right Lines being drawn parallel to the Meridian, shall be the Azimuths desired, which you must number according to the Situation of the Plain: Namely, the Western Azimuths on the East Side of the Meridian, and the East Azimuths on the West Side of the Meridian, as you see them numbred in Fig. 6. Plate 10.



C H A P. VI.

How to inscribe the Circles of the Sun's Altitude into Dial-plains.

THE *Almicanters*, or Circles of Altitude, in the Sphere, have the same Habitude to the Azimuths, or Vertical Circles, as the *Parallels* of Declination have to the Meridians, or Hour-circles: And therefore, the *Equinoctial* it self, and all the *Parallels* of Declination in a *Polar-plain*, are perfect Circles, and so are the *Almicanters* or Circles of Altitude upon an *Horizontal Plain*, as in Plate 10. Fig. 7.

Horizontal Plains, which lie parallel to the Horizon, have the Zenith for their *Poles*; so that for the Inscription of them upon these *Plains*, the Foot of the perpendicular Stile must be the Center upon which to describe them.

For the Numeration of these Circles, when they are described, there are two Ways most in Use: The one by Degrees and Minutes of the Sun's Altitude; the other according to the Proportion that the Height of any upright Object (as a House, Steeple, &c.) bears to the Shadow of it: The last of which I have here followed in this Figure 7. where the Circles of Altitude are equal, double, triple, and quadruple to the Altitude of the perpendicular Stile.

THE Inscription of these Circles into all other *Plains*, are, in a kind, the same with the Inscription of the *Parallels* of Declination: Only, where-



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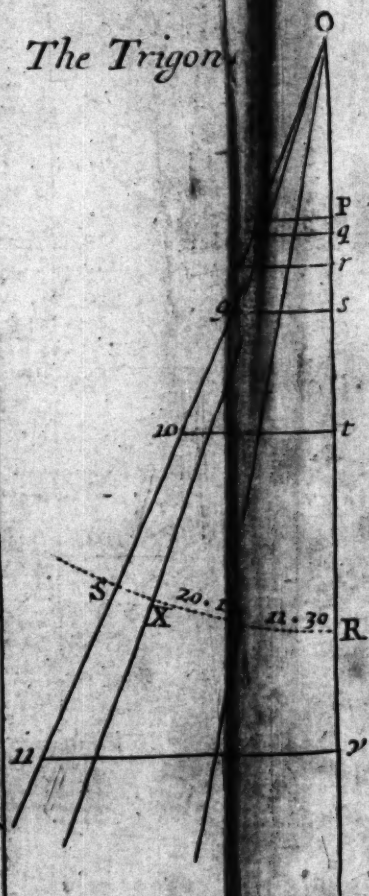
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Fig. I. is a detailed diagram of an East Dial. It features a horizontal line at the top labeled A-B and a vertical line on the left labeled M-N. A point Q is located on the horizontal line. A quarter-circle arc is drawn from Q to a point L on the horizontal line. From Q, several dashed lines radiate downwards and to the right. A series of solid lines, labeled with Roman numerals IV, V, VI, VII, VIII, IX, X, XI, and XII, originate from the horizontal line and extend downwards and to the right. A series of solid lines, labeled with letters H, G, F, E, D, C, B, A, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, originate from the vertical line and extend downwards and to the right. The intersection of these lines forms a grid. The text "An East DIAL" is written in a large, stylized font. Below it, the text "with 12 Parallels of the 12 Signs and Azimuths." is written in a smaller, cursive font. The diagram is labeled "Fig. I." in the top right corner.

The Trigon



*A South Dial with the Babylonish and
Itallian Hours & Durnall Arches.*

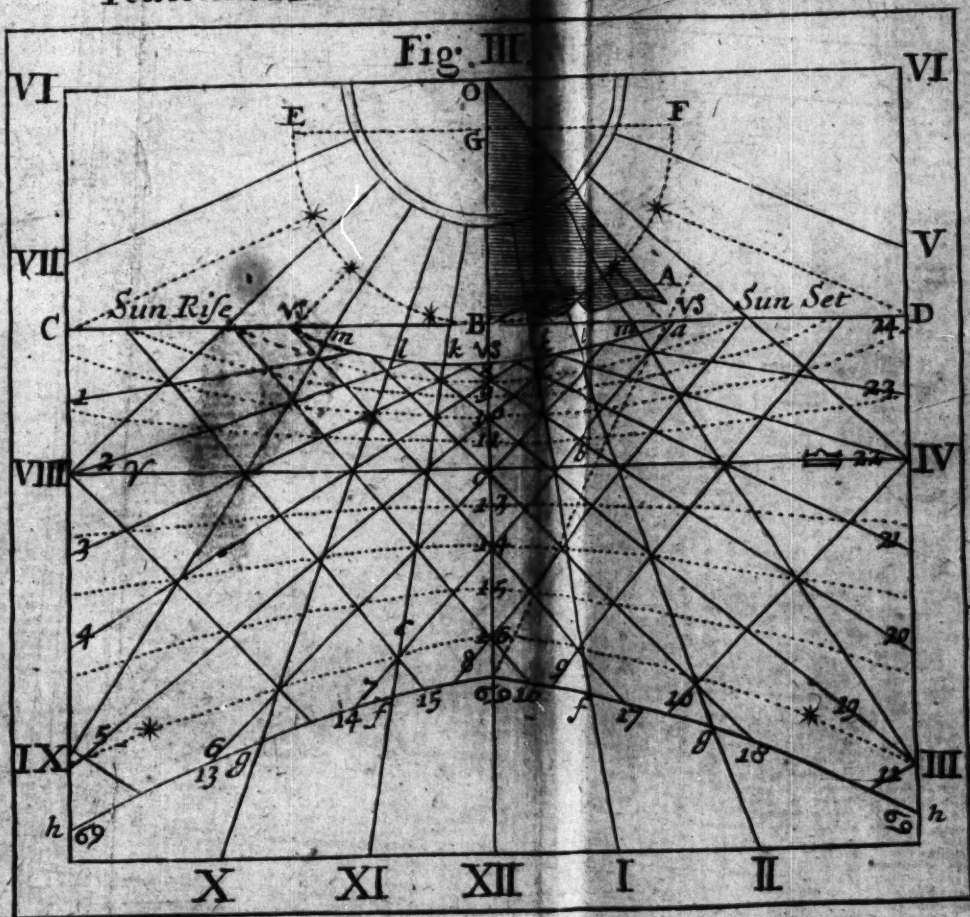
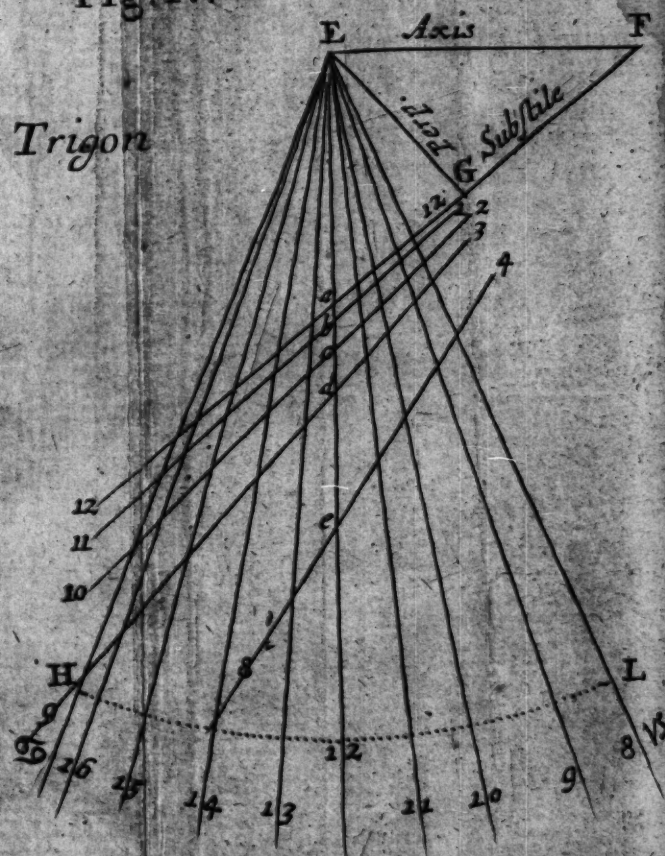


Fig. IV.
Trigon



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as in inscribing of the *Tropicks*, and other *Parallels* of Declination, you take the *Hour-lines* out of the *Dial-plain*, and put them into a Trigon; so in the Inscription of these you must take the *Azimuth Circles* out of your *Plain*, and put them into a Trigon, and from thence transfer them back again to your *Plain*, as in the other: And as the *Hour-lines* in the other must be first drawn upon the *Plain*; so in this must the *Azimuths* be first inscribed: And because these *Circles of Altitude* are smaller *Circles* of the *Sphere*, as the *Tropicks* and *Parallels* of Declination were, they will upon all *Plains* (the *Horizontal* excepted) be *Conick Sections*.



CHAP. VII.

A general and easy Way to project Hour-lines upon all kind of Superficies, without any Regard had to their standing, either in Respect of Declination, Reclination or Inclination.

IF a Point be assigned upon any Superficies, flat, or curved, one or more, wherein the *Hour-lines* and *Axis* shall concur; how to project the Hours to that Point, and to set up an *Axis* after the ordinary Manner, to give Shadow to them, without any Knowledge how the Dial standeth in respect either of Reclination, Declination, or Inclination.

First, To the Point assigned (upon any Side of it) by the help of a Semicircle, or other Level, stretch out an *Horizontal Thread*, serving for the
Horizon-

Horizontal-line; which Line need not be one single Line, but may be turned at one or more Angles, provided that it lie (all the parts of it) totally in the Superficies of the *Horizon*.

Secondly, With a perpendicular Thread held up, project the Sun upon the assigned Point, and into the *Horizontal Thread*, and stick in a Pin, or make a Mark upon the same *Horizontal-line*, thro' which the Shadow cutteth, and at the same Instant also take the Sun's Altitude.

Thirdly, By the Altitude taken find out the Sun's Azimuth; this Azimuth, whatever it be, is represented by the Mark formerly made in the *Horizontal-line* or Thread.

Fourthly, Apply a *Past-board* to the assigned Point, and hold it flat, that it may answer to the *Horizontal Thread* also; and upon this *Past-board* protract your Azimuth by a Thread extended from the Point assigned for the Center to the Mark upon the *Horizontal Thread*. Which done,

Fifthly, By help of that Azimuth upon the *Past-board*, protract the Meridian-line, observing the true Coast and Quantity of the Angle from the Azimuth; and to the Meridian thus found, describe an Horizontal Dial for the place.

Sixthly, Apply the *Past-board* to its place again, all things standing right as before; project all the Hours into the *Horizontal Thread* from off the *Past-board*, and set Marks upon the same Line, for the point of each several Hour, which Marks may be little Knots to slip to and fro upon the same Thread.

Seventhly, Project the *Meridian Point* by a perpendicular Thread upon some Object into that place whereabouts you imagine the Axis of the World would pass, above or below, from the point assigned for the Center.

Eighthly,

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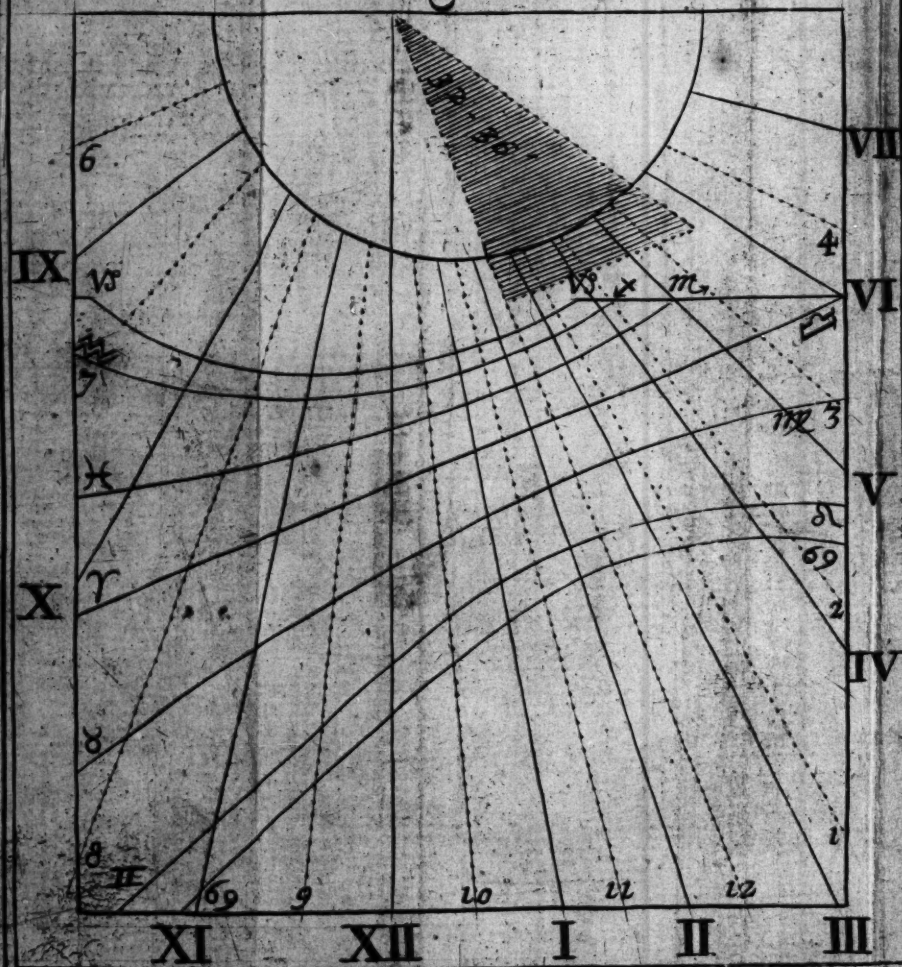
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Fig. V.



A Declining Dial, with Parallel Length of y Day, Azimuths, and

Fig. VI.

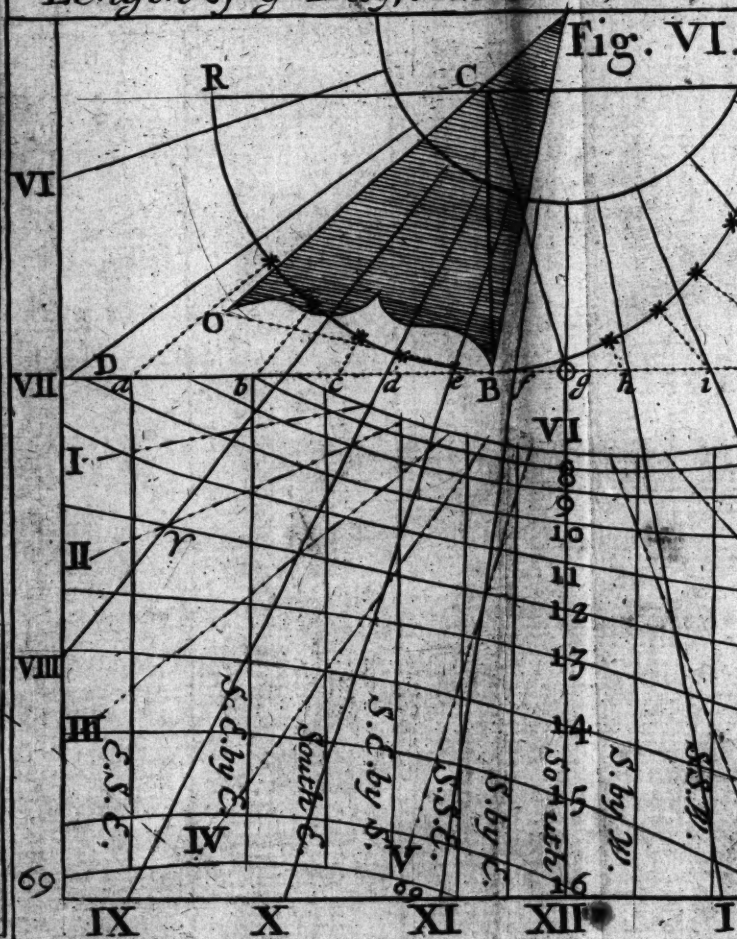


Fig. VI.

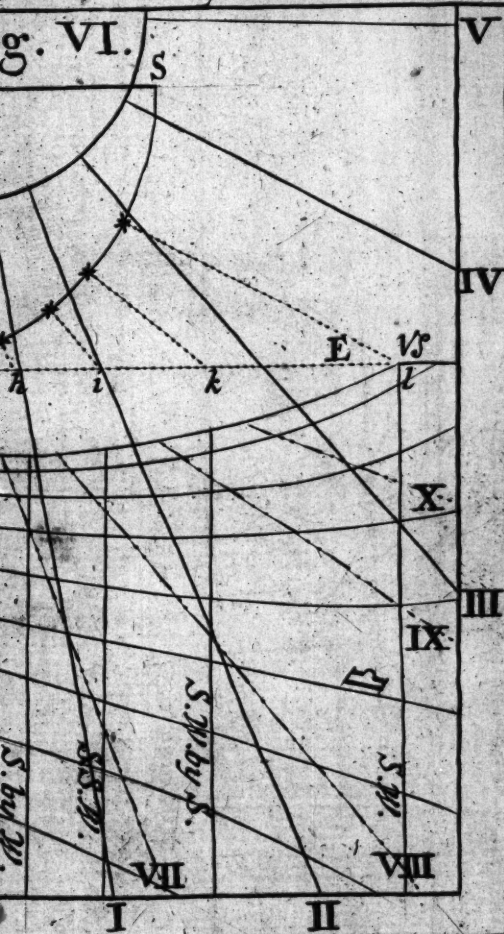


Fig. VI.

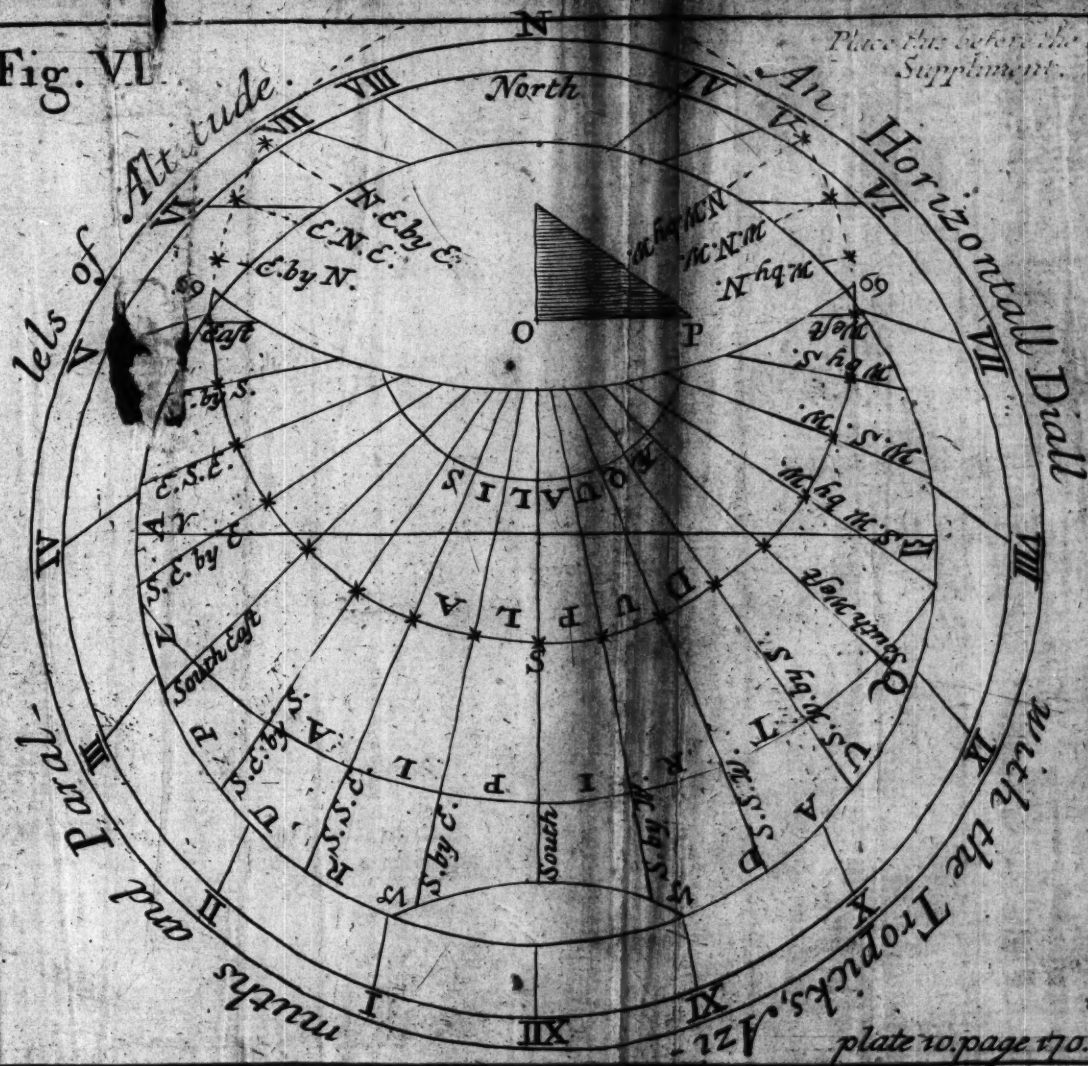
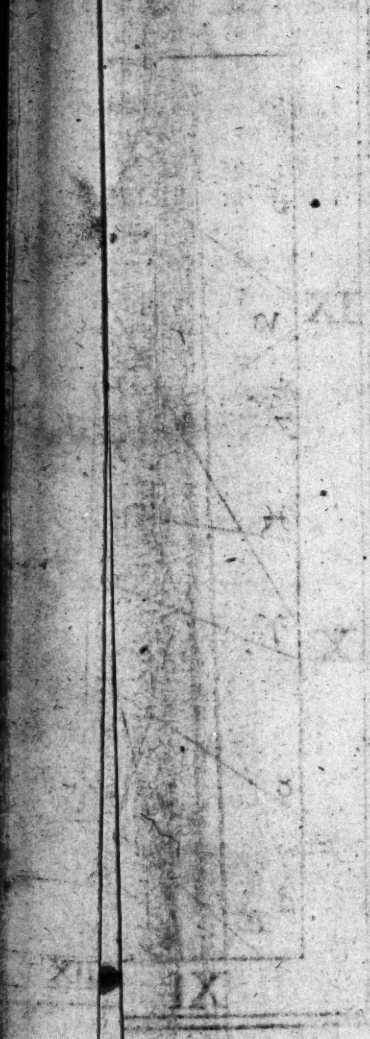


plate 10. page 170.



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Eighthly, With your Semicircle, (or a String and Quadrant) elevated or depressed, (as it shall be required) from the point assigned for the Center, according to your Latitude, project the *Pole* of the World.

Ninthly, Extend a Thread from the *Point* assigned for the Center to the *Poles* of the World, which shall represent the *Axis*.

Tenthly, By the *Point* upon the Horizontal Thread, and this *Axis*, (either by your Eye, laying the *Axis* to the Hour-points, or laying the Hour-knots to the *Axis*;) you may project all the Hours, and draw them: ——— Or else you may let the *Axis* alone, and content your self with the *Pole-point* projected into the Meridian: For if from the *Point* assigned to be the Center, or Meeting of the Hours and *Axis* you extend a Thread to each *Hour-point* in the Horizontal-line, and do repose (with your Eye) the same Thread upon the *Pole-points*; then shall the Shadow of the Thread give you that Hour-line; and do so in all the rest.

Eleventhly, Your Thread or *Axis* lying in its true Situation, you may easily fit an *Axis* to the same Posture. If your Dial be described upon a plain Superficies, you may then (by one side of a Square, applied to the Thread or *Axis*, and the other side lying upon the *Plain*) find out the Substile, and measure from it the Elevation of the *Plain*.

———— But if the Dial be described upon a curved Superficies, you must be content to set up your *Axis* by the Direction of the Thread only.

Twelfthly, This *Point* assigned for the Center, being a *Point* of the *Axis*, is, as it were, the *Apex* of the *Gnomon*, unto which all the Work is projected: But if it be required to set up an *Axis* to such a Superficies, upon which the Hours and *Axis* wil not meet in any tolerable manner, because

cause perhaps the *Axis* may be but of a very small Elevation above the Superficies, and yet an *Axis* is required, in this Case set up any point (of wire, or such like) of such Distance from the Superficies, as that the *Hours* and *Axis* may be distinct; and through that point let it be required to make the *Axis* pass; you have no more to do but only to project to this point as before, by letting the Shadow of a perpendicular Thread pass through that point, and noting the same upon the *Horizontal Thread*, and counting that End of the Wire as your Center, proceed as before; for the Thread that lies to project the Hours is a Pattern for the *Axis*.

THIS Way is general, serving to project the Hour-lines upon many Superficies, be they plain or curved, and however situate, whether contiguous or separate, and that without any laborious Inquisition after any of their Situations in respect of Declination, Reclination or Inclination.



CHAR.



C H A P. VIII.

How from a Glass Horizontally placed, to reflect Hours upon any Superficies, flat or curved, one or more.

FIRST, The Glass being placed truly *Horizontal*, observe the Spot of Light that the Sun casts, and make a Mark at it.

Secondly, And observe immediately the Sun's Altitude, and find the Azimuth.

Thirdly, Then extend an Horizontal Thread in the same Level with the Glass, but within the Room.

Fourthly, Project the Azimuth into the *Horizontal Thread*, by holding up a *Perpendicular Thread* in such a place, that tho' it hang at Liberty, you may at once discern both the Mark of the Spot of Light, and the Glass likewise; and then observe where the perpendicular Thread seems to cut the *Horizontal Thread*, and at that apparent Intersection make a Mark upon the Horizontal Thread for the Azimuth.

Fifthly, Apply a *Past-board* to the Glass, so that it may be stayed upon some Rest, that after it is taken away, it may be restored into its place again with all Exactness: Let it be also placed *Horizontally*, so that it may have full Relation to the *Horizontal Thread*.

Sixthly, At the Glass's Center make a Point for the Center upon the *Past-board*, and extending a Thread from the Center of the *Past-board* to the Mark

Mark of the *Azimuth* upon the *Horizontal Thread*, draw upon the *Past board* that Line, which the extended Thread Figures out thereupon; afterwards unto the same *Azimuth* upon the *Past-board* draw a Meridian Line, and to it an Horizontal Dial; and applying the *Past-board* again to its first Situation, project the Hours thereon unto the Horizontal Thread, and there make Marks or Knots.

Seventhly, Then project the Meridian (by a perpendicular Thread, covering in Appearance both the Knot at 12, and the Glass) unto the contrary Coast to that, wherein the *Pole* is elevated above the Horizon; that is to say, in our Northern Climates, you must project the Meridian Southward from the Glass, because the North *Pole* is elevated: And in the Meridian elevate your Semicircle, or extend a Thread and Quadrant from the Glass Southwards, till the *Plummet* falls upon your Latitude, so shall it point out upon some Object set to receive it, the North *Pole* reflected.

OR else, if this be not convenient, (because in Windows, which look towards the South, the North *Pole* will be without the Room, (and so the *Axis* above the Glass extended towards that *Pole* will be without also) you may in such Cases find out the opposite *Pole* to it, that is to say, that *Pole* which the former reflected *Axis* being extended through the Glass, and below it, would sign out, and that may be effected in this Manner.

Eighthly, Project the Meridian Line towards the *Pole* that is elevated, that is with us, towards the North *Pole*; and then (because the North *Pole* is elevated by Reflection towards the South, so, by the same Reason, the South *Pole* must be depressed

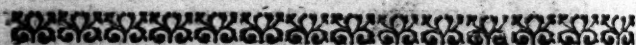
sed towards the North) by your Semicircle, or String and Quadrant, directed even with the Center of the Glass, expresse or project your Latitude downwards, (but towards the North) so shall the Semicircle or Thread point out the reflected South Pole in the Meridian. Now, whether you will, or can (most conveniently) use the reflected South Pole below it, you are to take your Choice, for both the one and the other of them do represent the reflected *Axis* of the World.

Ninethly, By this reflected *Axis*, and the Hour-points signed out upon the Horizontal Thread, you may easily project the reflected Hours, upon any kind of Superficies, one or more, whatever they be, that stand in the Way.





Geometrical DIALLING,



CHAP. IX.

How to make a plain Dial (either South or Horizontal) that shall give you the Hour of the Day at any Place or Places assigned, as well as at the Place the Dial is made for, according to the English Way of reckoning.

FIRST, Make a common plain Dial either South or Horizontal, as you would have your Dial to be; only in this Case it is best to place the Hours in a Circular Form, as you see *Plate 11.* it done; then (besides the two Circles, *Fig. 1.* between which the Hours are placed) draw so many Concentrick Circles as you would have Places in the Dial, and behind the Stile in each Circle put the Name of the Place whose Hour it represents; then observe what Difference of Longitude the Places proposed have from *London*, and by allowing 15 Degrees for an Hour, place the Hours with so much Difference as the Difference of Longitude requires, the Shadow

dow shall give the true Hour at any of the Places proposed. But because in this Case a Table of Latitude, &c. of Places is necessary, I shall insert the most correct Table of that Kind now extant, an Example of each of the above-mentioned Dials.

A Correct TABLE of the Latitudes and Difference of Meridians from *London*, of the most eminent Places in the World, mostly corrected by Celestial Observations.

Names of Places.	Latit.		Diff. Merid	
	D.	M.	H.	M.
<i>A</i> Capulca in Mexico	17	30	7	5 W
Agra, the Mogul's Court	28	30	5	33 E
Aleppo in Syria	37	20	2	25 E
Alexandria in Egypt	31	7	2	12 E
Amsterdam in Holland	49	54	0	9 E
Amiens in France	52	21	0	19 E
Antwerp in Brabant	51	10	0	17 E
Avignon in France	43	51	0	18 E
Babylon in Chaldea	34	30	3	15 E
Barbadoes	13	30	3	53 W
Barcelona	41	26	0	10 E
Batavia in Sumatra	6 S	15	6	43 E
Bayon	43	29	0	6 W
Bengal in India	21	56	6	21 E
Bergen in Norway	61	00	32	E
Bononia in Italy	44	30	0	47 E
Boston in New-England	42	25	4	42 W
Brest in France	48	23	0	18 W
Bordeaux in France.	44	50	0	2 W

Cadiz

Names of Places.	Latit.		Diff.	
	D.	M.	H. M.	
<i>Cadiz in Spain</i>	36	16 0	30	W
<i>Calais in France</i>	50	57 0	7	E
<i>Camboia in Italy</i>	10	20 7	12	E
<i>Canea in Crete</i>	35	29 1	37	E
<i>Candia</i>	35	18 1	41	E
<i>Cape Bona Esperance</i>	34 S	15 1	4	E
<i>Cape Comerin</i>	8	0 5	13	E
<i>Cape Verde</i>	14	43 1	9	W
<i>Cayon in the West Indies</i>	4	56 3	26	W
<i>Cayro</i>	30	4 2	17	E
<i>Ceylon</i>	7	50 5	33	E
<i>Cheusan in China</i>	30	0 8	6	E
<i>Cockin in the East Indies</i>	9	25 5	3	E
<i>Comimbra in Portugal</i>	40	30 0	39	W
<i>Constantinople</i>	41	7 2	7	E
<i>Copenhagen in Zealand</i>	55	40 0	50	E
<i>Corvo</i>	40	3 2	6	W
<i>Cracow in Poland</i>	50	10 1	18	E
<i>Cusco in Peru</i>	12 S	25 4	55	W
<i>Dantzick in Poland</i>	54	22 1	16	E
<i>Diep in Normandy</i>	49	56 0	4	E
<i>Dublin in Ireland</i>	53	12 0	28	W
<i>Dunkirk in Flanders</i>	51	1 0	9	E
<i>Durazzo in Dalmatia</i>	41	58 1	21	E
<i>Edinburgh in Scotland</i>	55	57 0	12	W
<i>Embsen</i>	53	5 0	30	E
<i>Pero Islands</i>	28	5 1	13	W
<i>Fez in Barbary</i>	33	10 0	24	W
<i>Florenzia</i>	43	41 0	47	E
<i>Frankfort</i>	50	4 0	33	E
<i>Geneva</i>	46	22 0	26	E
<i>Genoa</i>	44	27 0	39	E
<i>Ghent in Flanders</i>	51	1 0	15	E

Names of Places.	Latit.		Diff.	
	D.	M.	H.	M.
Goa in India	15	30	4	55 E
Goes in Zealand	51	30	0	16 E
Guardaloupa	14	04	9	W
Greenoble	45	16	0	24 E
Hamburg	53	41	0	42 E
Haver-de-grace	49	30	0	1 E
Heydelburgh	49	20	0	36 E
Hoaiguan in China	33	35	7	56 E
Jamaica Port Royal	17	40	5	4 W
Jerusalem	31	22	2	28 E
Ingoldstad	48	40	0	46 E
Insruck	47	15	0	47 E
Kebrook in New France	47	04	40	W
Koningsberg in Prussia	54	43	1	22 E
Leghorn	43	18	0	51 E
Leige	50	40	0	24 E
Leipsick	51	19	0	53 E
Lima in Peru	12 S	20	5	24 W
Lintz in Austria	48	16	1	0 E
Lions in France	45	45	0	20 E
Lisborn in Portugal	38	50	0	42 W
LONDON	51	32	0	0
Macao in China	22	13	7	44 E
Madagascar	19 S	29	2	58 E
Madrid in Spain	40	10	0	13 W
Majorca	39	35	0	10 E
Malacca Islands	2	42	6	40 E
Martinico	14	44	4	4 W
Marseilles	43	20	0	22 E
Messina in Sicily	38	21	1	6 E
Mexico	20	6	6	49 W
Montpellier	43	36	0	15 E
Moscow	55	34	2	35 E

Namur

Names of Places.	Latit.		Diff.	
	D.	M.	H.	M.
Namur	50	25	0	20 E
Nangasack in Japan	32	53	8	31 E
Nancy in Lorraine	48	39	0	27 E
Nantz	47	13	0	6 W
Naples in Italy	41	51	3	3 E
Narbonne	43	15	0	9 E
Narsinga	18	15	5	43 E
Nice, Provence	43	38	0	29 E
Ningpo, or Liampo in China	29	58	8	1 E
Noremburg	49	29	0	49 E
Olinda or Pernambuco	7	48	2	20 W
Oxford	51	44	0	5 W
Ozaca in Japan	35	5	8	52 E
Padua in Italy	45	31	0	45 E
Paris in France	48	50	0	9 E
Pekin in China	39	55	7	51 E
Poudscherrri	11	54	5	21 E
Prague in Bohemia	50	40	0	58 E
Ratisbon	48	59	0	49 E
Reggio in Italy	42	15	0	55 E
Rhodes in Germany	36	42	2	12 E
Rochel	46	10	0	5 W
Rome	41	51	0	52 E
Rostock	54	10	0	51 E
Rotterdam	51	55	0	17 E
Salamanca in Spain	41	12	0	16 W
Seville	37	36	0	26 W
Siam in India	14	18	6	43 E
Smyrna	38	28	1	49 E
Spahan in Persia	36	14	4	20 E
Stockholm in Sweden	58	50	1	10 E
Syracuse in Sicily	37	41	1	1 E
Tangier	35	55	0	25 W

Tidore

Names of Places.	Latit.		Diff.	
	D.	M.	H.	M.
<i>Tidore</i>	0	36	6	37 E
<i>Toledo in Spain</i>	39	46	0	14 W
<i>Toulon in France</i>	43	6	0	23 E
<i>Tripoly in Barbary</i>	32	54	0	52 E
<i>Tubing in Germany</i>	48	34	0	37 E
<i>Valencia in Spain</i>	39	30	0	3 W
<i>Venice</i>	45	18	0	50 E
<i>Vienna</i>	48	22	1	9 E
<i>Upsal in Sweden</i>	59	0	1	12 E
<i>Uraniburg</i>	55	54	0	51 E
<i>Utrecht</i>	52	5	0	20 E
<i>Wittenburgh in Saxony</i>	51	53	0	52 E
<i>Wolfembuttel</i>	52	11	0	44 E
<i>York.</i>	54	0	0	4 W

NOTE, In the Column of *Latitudes*, where S is placed it is South *Latitude*, and all the rest are North.

I shall now proceed to apply the foregoing Directions to Practice, and shall instance first in a Horizontal Plain Dial, which should be required to give the Hour of the Day at *London*, *Mexico*, and *Jerusalem*.

First, Draw a Horizontal Dial by the Directions given Chap. 3. Of *Geometrical Dialling*, Page 37. which reduced to a Circular Form, will appear as in Plate II. Fig. 1. where the middle Circle of Figures represents a Dial for the Meridian of

I

Lon-

London, then within that Circle of Figures draw the Concentrick Circle *a b c d* for *Mexico*. Also with it draw the Circle *e f g h* for *Jerusalem*, (or you may draw them both within or both without, but the other is more proper, because one Meridian is East, the other West from *London*) then behind the *Stile* in the inner Circle write or engrave (*Mexico*) in the Middle (*London*) in the outermost (*Jerusalem*); then having Recourse to your Table, you find that *Mexico* is West from *London* 6 Hours 49 Minutes, (or which is the same) when it is 12 a Clock or Noon at *Mexico*, it is 49 Minutes past 6 Afternoon at *London*; therefore lay a Scale from *Q*, the Center of the Dial, (which in this Case is not confined to the Center of the Circle) to 49 Minutes past 6 in the middle Circle for *London*, and there make a Stroke within the inner Circle, which shall be the Hour-line of 12 at *Mexico*: Likewise lay a Scale from the Center *Q* to 49 Minutes past 6 in the Circle for *London*, and there in the inner Circle for *Mexico*, place the Hour-line of 11, and so proceed round the Dial to lay the Scale to 49 Minutes past every Hour backwards from 6, you have the Hours from 12 to 11, 10, 9, 8, &c. at *Mexico*, and the same Shadow that gives the Hour at *London* in the middle Circle, gives at the same Time the true Hour at *Mexico* in the inner Circle.

EXAMPLE.

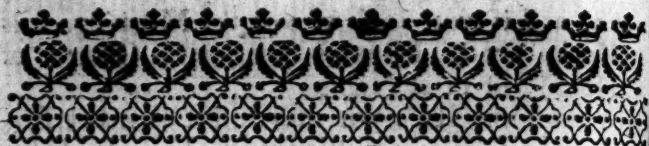
SUPPOSE I go to my Dial in the Forenoon, and find the Shadow of the *Stile* in the Line *Q k*, I find it is half an Hour past 9 at *London*, and in the inner Circle it is not quite three Quarters of an Hour past 2 in the Morning, viz. 41 Minutes past

past 2, and if you look at 6 in the Morning, it is at *Mexico* but 11 Minutes (*viz.* not a Quarter of an Hour) past 11 at Night.

By the same Rule you may insert as many Places in your Dial as it will contain *Concentrick Circles*, and thereby give at one View the Hour at all the most remarkable or remote Places in the World.

THE same Method is to be observed in any other Dial, whether *Direct*, *Declining*, *Inclining*, or *Reclining*, by placing the Hours at so much Difference, as is the Difference of Meridians between *London*, (or any other Place that the Dial is made for) and the Place assigned; but that the Learner may not be at a Loss, I have likewise drawn a Specimen of a South *Plate II.* Dial for *London*, *Jerusalem* and *Alex- Fig. 2.* *ico*, by which any Person may do the like for any other Places, and the Method so easy and intelligible, that it is not necessary to spend any more Time in Directions about it.

Note, You may by these Tables find the Hour at any Place assigned, without having it put upon a Dial, by subtracting the Difference of Meridians from the Time at *London*, if the Place be West from *London*, or adding if it be East, and thereby having the Time of any Eclipse, new or full Moon, &c. at *London*, may know at what Hour and Minute it is at any Place mentioned in the Table.



C H A P. X.

Instrumental DIALLING.

SECTION I.

*Teaching how to draw the Hour-lines upon any Plain,
by the Help of the Line of Hours, Inclination,
&c.*



THESE Lines may be inscribed on the Side of any *Dialling Scale*, *Sector*, or any other Instrument of Brass or Wood, and they are commonly known by the Name of the Line of Hours, Inclination, and Latitude, and if you have them upon any plain Scale, you ought to have Chords to several Radius's; but in this Case I would rather recommend a *Sector*, because there you may take Chords, Sines, or Tangents to what Radius you please.

THE first of those Lines is the Line of Hours, commonly known by the Word (Hours) at the Beginning of the Line; it contains 6 Hours, and is numbered with unequal Divisions from I to VI.

THE next to that, and close to it, is the Line of Inclination, known by this (*Incli.*) at the Beginning of it, and is 90 Degrees, divided in the same Proportion as the 6 Hours are, so that every 15 Degrees in one is an Hour in the other, to shew how many Hours and Minutes of Time answers to any given Number of Degrees and Minutes of the Equinoctial.

E X A M P L E.

I would know how many Degrees and Minutes of the Equinoctial is contained in an Hour and a half of Time. Look against an Hour and a half on the Line of Hours, and under that on the Line of Inclination you find 22 deg. 30 min. and so much is contained in an Hour and a half of Time.

THE next is the Line of Latitude, marked (*Lat.*) at the Beginning.

SOME have two Lines more, one marked (*G Pol.*) and the other (*L Pol.*) but by a Sector those Lines may be more commodiously supplied from the Tangent; but I shall shew the Use of both, and to avoid Prolixity, I shall fall directly upon Examples of the Use of these Lines in making Dials upon any Plain.





SECTION II.

*How to draw the Hour-lines on a Horizontal Dial,
for Latitude 51 deg. 32 min.*

FIRST, Draw the Line E W for the six a Clock Line, and at right Angles thereto draw the Line N S for the 12 a Clock Line to bissect the former, where you intend to have the Center of your Dial as at A.

THEN fixing one Foot of your Compasses in the Beginning of your Line of Latitude, extend the other to 51 deg. 32 min. the Latitude of the Place, and set that Extent from A to E, and from A to W; then take in your Compasses the whole Scale of Hours, and with that Extent and one Foot in E or W, with the other Foot cross the Meridian, or 12 a Clock Line in S, and draw the Lines E S, and W S.

THEN take in your Compasses the Distance upon the Line of Hours from the Beginning of the Line to I, and set that Distance from S to 1 and 11, and also from E to 5, and from W to 7; take also the Distance from the Beginning of the Line to II on the Scale of Hours, and set from S to 2 and 10, and also from W to 8, and E to 4: Also the Distance from the Beginning of the Line to III, and set from S to 9 and 3, which will also be equal to the Distance W 9, or E 3. Now Lines drawn from the Center A through these Figures, 7, 8, 9, &c. to the Limb of the Dial (which may be square or Round in what Form you please) gives the

the true Hour-lines of that Dial only for the Hours before 6 in the Morning, viz. 4 and 5, and likewise 7 and 8 at Night, they must be continued through the Center from their opposite Hours, and then are your Hour-lines finished; and for the Stile, it must be a Plate of Brass, or the like, to make an Angle of $51^{\circ} 32'$ (the Latitude of the Place) with the Plain, the Angular Point being fixed just at the Center A, and the Stile standing upon the Meridian Line at right Angles with the Plain of the Dial, and then is your Dial finished.

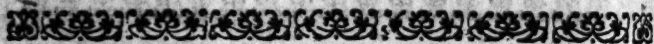


SECTION III.

How to draw Hour-lines upon a direct South Dial.

THE same Directions, that serve for a *Horizontal Dial*, may with a little Alteration serve for drawing the Hour-lines upon a South Dial, for if instead of taking the Latitude of the Place off from the Scale of Latitudes, you take the Complement, proceed in all Respects as before, only number the Hours the contrary Way, it will produce a South Dial. The Reason is, because as the North Pole is elevated above the Plain of the Horizontal Dial, equal to the Latitude of the Place, so the South Pole is elevated above the Plain of the South Dial, equal to the Complement of the Latitude of the Place. Therefore if you would make a South Dial for Latitude $51^{\circ} 32'$ take $38^{\circ} 28'$ min. the Complement of the said Latitude, (or if you work for any other Latitude, take always the Complement of the Latitude you work for)

out of your Scale of Latitude, and work in all Respects as you did before, only accounting the Meridian-line for the Hour of 12, number the Figures the contrary Way, viz. to the right Hand of the Meridian, as Practice and even Reason it self will inform you; and as in the other the Stile made an Angle with the Plain of the Dial equal to the Latitude of the Place, so the Stile in this must make an Angle with the Plain of the Dial equal to the Complement of the Latitude, and both stand at right Angles with, or perpendicular to the Plain.



SECTION IV.

Of a Direct North Dial.

A North Dial is the same in all Respects with a South Dial, only in a North Dial the Stile points upwards towards the North Pole, because the North Pole is elevated above the Plain of that Dial equal to the Complement of Latitude; for it is an universal Rule in all *Dials* that shew the Hour of the Day by a strait lined Stile, to have that strait Side of the Stile, whose Shadow gives the Hour, to lie parallel to the Axis of the World, and to point directly to that Pole which is elevated above the *Plain* of the *Dial*: And the Divisions for the Hour-lines are the same, as in a South *Dial*, if they were to be inserted; but as it would be superfluous to describe Hours which could never be shew'd by the Sun, it is proper to omit the Hours about Midnight, viz. 9, 10, 11, 12, 1, 2, 3,

at

at which Hours the Sun is under the Horizon, even at the longest Day, in the Latitude of *London*, but if you work for a more Northerly Latitude, you must put on more Hours; as suppose you should make a North *Dial* for Latitude 64 deg. 00 min. the longest Day there is 20 Hours 24 Minutes, its Complement to 24 Hours is 3 Hours 36 Minutes, the Length of the Night at that Time; half the Length of the Night is always the Time of the Sun's Rising, which in the fore-mentioned Latitude 64 deg. is 1 Hour 48 min. for the Time of Sun's Rising in the Morning, and half of 20 Hours 24 min. viz. 10 Hours 12 min. is the Time of Sun's setting at the longest Day in that Latitude: But that the Artist need not be put to the Trouble of Calculation, I have inserted a Table, which shews the Length of the longest Day in all Latitudes, either North or South, viz. from *Pole to Pole*; and although the same Table extended from the Equinoctial to the Polar Circles, might have served in common Uses, yet for the Satisfaction of the Curious, I have inserted the whole as follows,



A TABLE shewing the Length of the longest Artificial Days, in all Places from the Equinoctial to the Poles of the World.

Height of Pole	Long- est Day H. M.	Height of Pole	Longest Day H. M.	Height of Pole	Longest Day D. H. M.
0	12 0	47	15 42	66	42 1 16
6	12 20	48	15 52	69	54 16 25
12	12 42	49	16 0	70	64 13 46
16	12 58	50	16 10	71	74 0 0
20	13 12	51	16 20	72	82 6 36
24	13 30	52	16 30	73	89 4 58
27	13 42	53	16 42	74	96 17 0
30	13 56	54	16 54	75	104 1 4
33	14 0	55	17 8	76	110 7 27
34	14 16	56	17 22	77	116 14 22
35	14 22	57	17 36	78	122 17 6
36	14 28	58	17 52	79	127 9 55
37	14 34	59	18 10	80	134 4 58
38	14 38	60	18 30	81	139 31 36
39	14 44	61	18 54	82	145 6 43
40	14 52	62	19 20	83	152 2 6
41	14 58	63	19 50	84	156 3 3
42	15 4	64	20 24	85	161 5 23
43	15 12	65	21 10	86	166 11 23
44	15 18	66	22 18	87	171 21 47
45	15 26	66½	24 0	89	176 5 29
46	15 34	67	24 Days	90	181 21 58
					187 6 39

THE Use of this Table is very easy, for in the first Columns you have the Length of the longest Day in any given Latitude in Hours and Minutes, and in the two last Columns you have the Length

Length of the longest Day in Days, Hours, and Minutes, the Sun in these Latitudes remaining above the *Horizon* during so many Days, while he is near his greatest *Declination*, of the same *Denomination* with the Latitude of the Place, whether *South* or *North*, and when the *Declination* is contrary, the longest Night is the same Length.

E X A M P L E.

In Latitude 60 deg. *North*, the *Longest Day* is 18 Hours 30 Minutes, which happens when the Sun enters *Cancer*, and hath 23 deg. 30 min. *North Declination*; but in 60 deg. *South*, the Day is the same length, when the Sun enters *Capricorn*, and so in the rest, but beyond Latitude 66 deg. 30 m. the Sun continues above the *Horizon* several Days, half of which is before the *Tropick*, and the other half after it.

E X A M P L E.

I desire to know the *Longest Day* in Latitude 71 deg. 00 min. and I find it in the Table 74 Days, viz. 37 Days before the *Tropick*, and as many after it, which is from the 4th of *May* to the 17th of *July*, in all which Time the Sun never sets in that *Latitude*.

By this Table the Artists may know by Inspection how many Hours are proper to be put upon any *Erect*, *Direct*, *North Dial*, or any *Horizontal Dial*, in any Latitude whatsoever.

SECTION V.

Of South or North Reclining Dials.

IN a Direct North or South Reclining Dial, there need be no Directions given, but what are already laid down, for all such *Dials* are *South Dials*, or *Horizontal Dials*, in some other Latitude; for a *Horizontal Dial* in Latitude $51^{\circ} 32'$ or any other Latitude, is only a *South Dial* Reclining 90° deg. for in an Erect *South Dial*, the *South Pole* is elevated above the Plain of the Dial, equal to the Complement of the Latitude; therefore if a *North Dial* in *South Latitude*, or a *South Dial* in *North Latitude*, recline equal to the Complement of the Latitude, the Plain of the *Dial* becomes parallel to the Axis of the World, and Style of the *Dial*, and then that becomes a *Horizontal Dial* under the Equinoctial, and hence these general Rules may be deduced.

1. If a *South Dial* reclines less than the Complement of Latitude, it becomes a *Vertical Dial* for a Latitude, so much more than the given Latitude as the Reclination is. Or more plain, Add the Reclination to the Latitude, the Sum is the Latitude, where that is an Erect or Vertical Dial.

EXAMPLE.

SUPPOSE I would make a South Dial for Latitude $51^{\circ} 32'$. North Reclining 22° deg. Add 22° d. to 51° deg. $32'$ min. the Sum is 73° deg. $32'$ min. there-

therefore make an erect direct *South Dial*, for Latitude 73 deg. 32 min. North, the same shall be a direct *South Dial* reclining 22 deg. for Latitude 51 32, and the Rules for making it are the same in all Respects.

2. IF the Reclination be equal to the Complement of Latitude, it becomes a *Horizontal Dial* under the Equinoctial, for Reasons before given.

— Therefore,

3. IF a *South Dial* in North Latitude (or a North *Dial* in South Latitude) recline more than the Complement of Latitude, it will be a *Horizontal Dial* for such a Latitude, as the Reclination is more than the Complement of Latitude: Or thus, subtract the Complement of Latitude from the Reclination, the Remainder is a Latitude; for which if you make a *Horizontal Dial*, it shall also be the *Dial* for the Latitude and Reclination proposed.

E X A M P L E.

I desire to make a *Dial* for Latitude 60 deg. North, to recline 40 deg.

SUBTRACT 30 the Complement of Latitude from 40 the Reclination, the Remainder is 10; therefore a *Horizontal Dial* for Latitude 10 North, is the same in all Respects as a *South Dial* reclining 40 deg. for Latitude 60 deg. North.

For it is plain, that if the *Dial* had reclined but 30 deg. the Plain had been parallel to the Axis of the World, but reclining 10 Degrees more, elevates the contrary Pole 10 Degrees, and becomes a *Horizontal Dial* for that Latitude.

UPON the same Ground we may deduce Rules for Incliners, for if we consider, that the Stile of all *Dials* should lie parallel to the Axis of the World,

World, and consider how much the Angle, that the Stile makes with the Plain of the Dial, is augmented or diminished by the Inclination of the Plain, it gives you the Latitude for which a *Vertical Dial* being made, it will be a North or South Dial with the given Inclination, and for the given Latitude, for which I think one Example sufficient.

EXAMPLE.

I would make a South Dial for Latitude $51^{\circ} 32'$ North, to incline 10° deg.

It is evident, that this Dial that inclines 10° d. would be vertical, or perpendicular to the Horizon in a Latitude 10° Degrees less, therefore for a South Inclining Dial in North Latitude, or North in South Latitude.

1. If the Latitude be more than the Inclination, subtract the Inclination from the Latitude, the Remainder is the *Latitude* where the same Dial is Vertical.

2. If the Inclination be equal to the Latitude, it is an *Equinoctial Dial* under the *Equinoctial*.

3. If the Inclination be more than the Latitude, subtract the Latitude from the Inclination, the remainder is the Latitude, where the Dial is Vertical, but of a contrary Denomination, viz. if the Dial is to be made for North Latitude it is Vertical, in South Latitude, & contra.

For Direction about East and West Recliners,
See Page 125.

SECTION VI.

How to draw Hour-lines upon a direct East or West Dial.

I Shall begin with an Example of an East Dial for Latitude 51, 32 North.

TAKE in your Compasses the Chord of 60, and with one Foot in C, draw the Arch A B, and set off the Complement of Latitude from A to B, and through B draw the Lines C, B, E, then somewhere towards the upper End of the Line C E as at R, draw G R F, perpendicular to C E for the Substile and Hour-line of 6, and draw H I parallel to E C, and at any competent Distance from it, then from one of the Lines marked (Pol.) on your Scale take the Distance from the Beginning of your Scale to I, and set that Extent from R to 5, and from R to 7; then take the Distance from the End of your Scale to H, and set from R to 4, and to 8, set also the Distance from the Beginning of the Scale to III, and set from R to 9, and so proceed to find the Hours of 10 and 11 by the Figures III, and V, upon the Scale and draw the Lines 4.4, 4.5, 7.7, &c. parallel to 6.6. These shall be the Hour lines required.

THE Distance from the Beginning of the Scale to III, is the Height of the Stile, and must stand upon the Hour-line of 6, and perpendicular to the Plain of the Dial, and then is your Dial finished.

THE making of a West Dial is all the same, only as the East *Dial* is elevated towards the left Hand equal to the Complement of Latitude, the West *Dial* is elevated towards the right Hand, and instead of 4 5 6 7 8 9 10 11, in the East *Dial*, you must upon the West Dial put on the Figures 12 3 4 5 6 7 8, because the Afternoon Hours are described upon the West Dial, as the Forenoon Hours are upon the East Dial.

BUT in working by those Lines you are confined to a certain Bigness for your Dial (except you enlarge it afterwards) and therefore I hold it much better in this Case, to make use of the Tangents upon the Sector; and having first considered how large you intend your Dial shall be, and consequently determined the Height of your Stile, take the Height of the Stile in your Compasses, and open the Sector, till the aforesaid Extent will just reach from the Tangent of 45 on one side of the Sector, to the same Tangent on the other side, and keeping the Sector at that Opening, take in your Compasses the Tangent of 15 deg. and set from R to 5 and 7; take also the Tangent of 30, and set from R to 4 and 8; the Tangent *Plate 11.* of 45, or Radius, which is also the *Fig. 2.* Height of the Stile, is the Hour-line of 9; and as every 15 deg. of the Equinoctial make an Hour of Time, so proceed to take the Tangent of 60 and 75, they give the Hour Marks for 10 and 11, from which drawing Lines cross the Dial parallel to 6 6, as before directed, gives the Hour-lines required.

Note, When you would take a Tangent less than 45, you must make the 45 at the End of the Sector Radius; but when you would take a Tan-

a Tangent above 45, you must make that 45 Radius, which is at the Beginning of the remaining Tangents, (which is also marked T) and proceed as before.



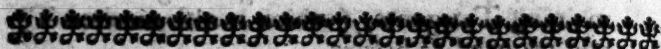
SECTION VII.

How to describe Hour-lines upon direct East or West Reclining Plains.

I Shall not trouble my self to give any Directions for drawing Hour-lines upon East or West Reclining Dials, considered as such; for as in Sect. 5. you have Directions how to find in what Latitude any North or South Recliner becomes a Vertical Dial or an Horizontal Dial, and it is also shew'd in P. 125, how to reduce any East or West reclining Plain to an erect declining Plain in another Latitude, or in what Latitude the given Plain shall be an erect Plain, and how much it declines; it will therefore be sufficient to shew how to draw Hour-lines upon all erect declining Plains, because in them all East and West Recliners are included.



SECT.



SECTION VIII.

To draw the Hour-line upon a North or South declining Plain.

I shall instance in a South Erect Plain declining Westward 24 deg. 20 min. for the Latitude of London, 51 deg. 32 min. North. (See Chap. 7. Page 46 and 47.)

HERE are two Things given, and 3 required before you can proceed.

Given	}	The Latitude	51	32
		The Declination	24	20
Required	}	The Substile's Distance from the Meridian		
		The Height of the Stile above the Plain.		
		The Inclination of Meridians		

For the Substile's Distance from the Meridian.

As Radius	10.000000
To the Sine of the Plain's Declination 24 20.	} 9.614944
So Tang. Comp. of Latitude 38 28	
	9.900086
<hr/>	
To Tang. of Substile's Distance from the Meridian	} 9.515030
18 9	

2. For the Height of the Pole (or Stile) above the Plain.

As Radius 10.000000
 To Sine Complement of Latitude } 9.793831
 38 deg. 28 min.
 So Sine Complement of Declination } 9.959596
 65 deg. 40 min.

To Sine of the Stile's Height above the Plain 34 deg. 32 min. } 9.753427

3. For the Inclination of Meridians.

As Radius 10.000000
 To Co-Tangent of Declination } 10.344650
 65 deg. 40 min.
 So is the Sine of Lat. 51 deg. 32 min. 9.893745
 To the Co-Tang. of the Inclination of Meridians 30 d. 01 m. } 10.238397

Or if you would confine your self to Instrumental Operations, the same may be performed upon the *Gunter's Scale* thus:

1. For the Substile's Distance from the Meridian.

THE Extent from Radius to the Sine of the Plain's Declination 24. 20. will reach from the Tangent Complement of Latitude 38 deg. 28 m. to the Tangent of the Substile's Distance from the Meridian 18 9.

2. For

2. For the Height of the Stile.

EXTEND from Radius to the Sine Complement of Latitude $38^{\circ} 28'$, the same Extent will reach from the Sine Complement of Declination $65^{\circ} 40'$, to the Sine of the Stile's Height, $34^{\circ} 33'$.

3. For the Inclination of the Meridian.

THE Extent from Radius to the Sine of Latitude $51^{\circ} 32'$, will reach from the Co-Tangent of Declination $65^{\circ} 40'$, to the Co-Tangent of the Inclination of Meridians $30^{\circ} 00'$.

THE Requisites thus found, draw the *Horizontal-line* H O, and in some convenient *Plate 11.* Part of that Line, as in C, fix the Center of your Dial, and from thence *Fig. 3.* draw C 12 perpendicular to H O, then with 60° deg. of the Chord, and one Foot in C, make the Arch y z, upon which set off $18^{\circ} 9'$ min. the Substile's Distance from the Meridian from y to x, and draw C x F, for the Substile.

Note, The Substile must be on the right Hand of the Meridian, because the Plain declines to the Westward, and should have been on the left Hand, if it had declined Eastward.

THEN through C, and at right Angles with the Substile, draw the Line A B, and from the Scale of Latitudes take $34^{\circ} 33'$ min. (the Height of the Stile) and set from C to A, and from C to B. Take in your Compasses the whole Scale of 6 Hours, and with one Foot in A or B, turn the other about, till it touch the Substile, as in F, and draw the Lines A F and B F.

FIND

FIND the Inclination of Meridians (which in this Example is 30 deg.) in the Scale of Inclinations, and against that in the Line of Hours you find 2. Therefore take 2 Hours in your Scale, and set from F to 12, and from B to 6. Take also 1 Hour off the Scale of Hours, and set from F to 1, and from B to 7. In the same manner take 3 Hours off the Scale, and set from F to 11, and from B to 5. Likewise set 4 Hours off the Scale, from F to 10, and from B to 4. Also set 5 Hours off the Scale, from F to 9, and from B to 3, and for the 2 a Clock Line it happens to fall just in the *Substile*, because the Inclination of the Meridian is just 30 deg. which at 15 deg. to an Hour, makes two Hours: And for the Hour of 8 in the Morning, continue the Hour-line of 8, which falls above the *Horizontal-line* on the right Hand, quite through the Center to the Edge of the Dial, and it shall be the Hour-line of 8 in the Morning, and for the rest, draw Lines from the Center C through the Marks 1, 2, 3, 4, 5, &c. to the Edge of the Dial, they shall be true Hour-lines for that Dial.

THE *Stile* must stand upon the *Substile*, and perpendicular to the Plain of the Dial, the back Part of the *Stile* that gives the Hour by the *Shadow*, making an Angle of 34 deg. 33 min. with the Plain of the Dial equal to the Height of the *Stile* before found.

Note, The Inclination of the Meridian being just 30 deg. the *Substile* falls just upon the *Hour-line* of 2, but if it had been any other odd Number, as suppose 35 deg. this found in the Line of Inclination, there is against it in the Line of Hours, 2 Hours 20 Minutes, then you must have set off from the Line of Latitudes 2 Hours 20 Minutes, from F to 12, and from B to 6, and 0 Hours 20 min.

min. from F to 2, and from B to 8, and so in any other Case.

IN drawing this Dial, you have likewise made 3 more, for which to avoid Repetitions, I shall refer you to Page 50 in the 7th Chapter, and to the Figures of them in Plate 3. Fig. 4.



SECTION IX.

How to draw Hour-lines upon a Dial that declines so far, that the former Directions will not be sufficient.

I Desire to draw the Hour-lines upon an erect Plain, declining from the South Eastward, 80 deg. Lat. 51 32.

(See the same Chap. 8 Page 51.)

YOU are already taught in the last Section, how to find the Requisites, which are by those Rules found to be as followeth.

	deg.	min.
Substile's Distance from the Meridian.	38	2
Height of the Stile.	6	12
Inclination of Meridians.	82	9

DRAW the Line H I, and with the Chord of 60, and one Foot in H, describe the Arch M N, and from M set off the Substile and Stile to make their respective Angles with the Line H I, viz. the Substile to make an Angle of 38 deg. 2 min. and the Stile to make with the Substile an Angle of 6 deg. 12 min. or with the Line H I an Angle of 44 deg. 14. and draw H C B for the *Substile*, and H K L to represent the Stile.

THEN

THEN in any convenient Place towards the lower End of the Substile, as at B, draw a Line at right Angles with the Substile, as the Line F B D, then with one Foot of your Compasses at the Beginning of your longer Polar Scale, extend the other to the Hour of 3, set that Extent from B to D, and through D draw the Line D E parallel to the Stile H K L, then is D E the augmented Stile. Then with one Foot of your Compasses in the Beginning of your lesser Polar Scale, extend the other to 3 Hours, and with that Extent place one Foot in the Substile B C H, carry it along the Substile, till the other Foot just touch the Line D E, which will be when the other Foot is in C, then make a Mark, and through C draw a Line parallel to the Line F B D, as the Line E C G; then find the Inclination 82 deg. 9 min. in the Scale of Inclination, and against it in the Scale of Hours you have 5 Hours 29 Minutes, which shews that the Substile falls between the Hours of 6 and 7 in the Morning (the Declination being Easterly) but had been between 5 and 6 in the Afternoon if it had been Westerly.

Now if the Hour-line of 12 be 5 Hours 29 Minutes from the Substile, the Hour-line of 11 must be 4 Hours 29 Minutes from it, &c. and the Hour-line of 7 is 0 Hours 29 Minutes from it, and if so, the Hour-line of 6 must be 10 Hours, 31 Minutes on the contrary Side, because 29 Minutes and 31 Minutes make just an Hour, &c. and all the other Distances, as in the following Table.

From

From B towards F.

From B towards D.

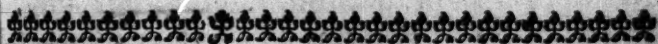
H. M.	Hour on the Plain.	H. M.	Hour on the Plain.
0	29 B	7	31 B
1	29 B	8	31 B
2	29 B	9	31 B
3	29 B	10	31 B
4	29 B	11	31 B

THE Use of this Table is very easily understood, for, take (according to the Table) 0 Hours 29 Minutes from the greater Polar Scale, and set from B towards F, it shall fall at the first * in the Line D B F. Take likewise 1 Hour 29 Minutes, 2 Hours 29 Minutes, 3 Hours 29 Minutes, &c. from the said greater Polar Scale, and set them upon the Line D B F, from B towards F, to the several Points * * * &c. and the contrary Way, set the Distances 0 Hours 31 Minutes; 1 Hour 31 Minutes, &c. upwards from B upon the same Line, to the Points * * * &c. it finds the Points for the Hours of 6, 5, 4, &c. do the same by the lesser Polar Scale from the same Table, and find the Marks * * * in the Line E C G; then laying a Ruler over the two Marks next below the *Substile*, a Line ruled thereby shall be the Hour-line of 7, and by the two next Marks, a Line ruled shall be the Hour-line of 8; and so in all the rest, as you see in the Figure.

THE

THE *Stile* in this, as in all others, must stand directly over the *Substile*, and must be a Plate of Iron or Brass, and in the Form of the Figure B C E D.

IN the making of this Dial, you have also made a *South Dial* declining West 80 deg. only for the Hours 6, 7, 8, 9, 10, 11, you must put 1, 2, 3, 4, 5, 6, &c. You have also made a *North Dial* declining East 80 deg. and a *North Dial* declining West 80 deg. with only inverting the *Stiles* and *Figures*, as you are taught Page 50, in the 7th Chapter before-mentioned, and the Figure (*Plate 3. Fig. 4.*) may sufficiently illustrate this also.



SECTION X.

Of Declining Reclining Plains, and how the Hour lines may be described on them.

ALTHOUGH we have elsewhere in this Book laid down several Methods for effecting this, yet in order to reduce the whole into as narrow a Compass as possible, we shall in this Section shew how those Declining Reclining Plains may be reduced to new Latitudes, and new Declinations, and may be made by the Directions given in Sect. 8. by the Lines on the Scale.

EXAMPLE.

It is required to make a South Plain for Latitude 51 deg. 32 min. North, to decline from the South-westward 24 deg. 20 min. and to recline from the Zenith 54 deg.

K

The

The Canon to find the new Latitude is,

As Radius		10.000000
To Sine Compl. Declin. 24 20		9.959596
So Tang. Compl. of Reclin. 54 0		9.861261

To Tangent 33 30	9.820857
------------------	----------

IN South Reclining Plains, as our Example is, the Difference between the Tangent last found (which here is 33 30) and the Latitude of the Place is the Complement of the new Latitude sought.

	deg.	min.
Latitude of the Place	51	32
Tangent found	33	30

Remains	18	2	whole
---------	----	---	-------

Complement 71 58 is the new Latitude sought. Only observe, that if the Tangent be more than the Latitude, the same Pole is elevated; if less, as here it is, the contrary Pole is elevated, and consequently, if they be equal, neither Pole is elevated, but it is an Equinoctial Plain.

But for North Reclines,

If the Tangent last found be equal to the Complement of Latitude, the Plain is a Polar declining Plain; but if greater or lesser than the Complement of Latitude, the Difference is the new Latitude.

The Canon to find the new Declination.

As Radius		10.000000
To Sine Compl. Reclin. 54 0		9.769219
So Sine of Declination 24 20		9.614944
To Sine of 14 deg. 1 min.		9.384163

THIS

THIS 14 deg. 1 min. is the new Declination, therefore if it be required to make a Dial for Latitude 51 deg. 32 min. to decline from the South-westward 24 deg. 20 min. and to recline from the Zenith 54 deg. 00 min. you may proceed (by the Directions given, Chap. 7. Page 46. of *Geometrical Dialling*, or Part 3. Sect. 3. and 8. in Pag. 129, and 141.) to make an upright Dial for Latitude 71 58 (the new Latitude) and to decline 14 deg. 1 min. from the South, (according to the new Declination found) that Dial shall serve for the Dial required.

Note, The Declination thus found, is always less than the old Declination was, but is always the same Way, viz. East or West, as the old Declination was.

BUT to apply this new Dial to the Plain proposed, you must not place the Meridian or Hour-line of 12 perpendicular to the Horizon, but it must make a certain Angle with the *Horizontal-line* of the Reclining Plain, which we call the Meridian Ascension or Descension, which is found thus :

As Radius		1.000000
To Sine of Reclination	54 0	9.907958
So Tang. of old Declinat.	24 20	9.655348

To Tang. of 20 deg. 6 min. 9.563306
whose Complement 69 deg. 54 min. is the Angle that the Meridian makes with the Horizon.

HAVING thus obtained the Meridian, Ascension or Descension, viz. the Angle that the Meridian makes with the Horizon, your next Work is to find the Position of the Meridian-line and Substile, for which see the three following Pages.

In { North Incliners. South Recliners.	{ Less than Equinoctial the Meridian must be drawn.	{ above below	{ That End of the Horizontal Line, which lies contrary to the Coast of the Plain's Declination.
	{ More than Equinoctial, the Meridian must be drawn.	{ below above	{ That End of the Horizontal Line, which lies the same Way with the Coast of the Plain's Declination.
In { North Recliners South Incliners.	{ Less than a Polar the Meridian must be drawn.	{ above below	{ That End of the Horizontal Line, that looks the same Way with the Coast of the Plain's Declination.— And this Meridian thus drawn in North Recliners, represents 12 at Night.

Equal to a Polar the Meridian must be drawn below the Horizontal Line at that End which is contrary to the Coast of Declination, and the fix of Clock Hour-line is always the Substile.

North Re-
cliners.
In } South In-
cliners.

And from that end of the Horizontal Line, which lies contrary to the Coast of the Plains Declination.— And in South Incliners it is only serviceable to help to draw the rest of the Dial.

below } above

More than a Polar the Meridian must be drawn

1. To know which Way the Substilar Line of any Dial must stand from the Vertical Line of the same Plain. And,

2. How to order your Work in the Southern Hemisphere.

For the First.

Upon all Plains whereon the

North Pole

South Pole

is elevated, the Substilar must
lie from the

Upper End

Lower End

of the Vertical Line
toward the full

North

South

For the Second.

ALL the Rules, Precepts and Examples given in this Case, do suppose you to be in the Northern Hemisphere of the World; therefore if you should be in a Southern Hemisphere, these Precepts will serve there also, by only changing the Words North and South one into the other, as for South read North, and for North read South, and so Northern for Southern, and the contrary.

For placing your Dial, draw an Horizontal Line upon your Plain, and set off so many Degrees by the Help of your Line of Chords, as the Distance of the Meridian and Horizon is found

to

to be, and to the right Coast; there draw your Meridian-line, then apply your Paper Draught to your Plain, laying the Meridian-line of your Paper Draught exactly upon the Meridian-line (now found) upon your Plain, and take Care that the Substile lie according to the Directions now given, and that the Stile do always point towards the Pole, that is elevated above your Plain, and then by pricking through your Paper, or any other convenient Means, you may transfer the Hour-lines, &c. to your new Plain, and drawing the Hour-lines you have the Dial required.

As for East or West Recliners or Incliners, the reducing them to erect Decliners in other Latitudes, and the Meridian-line in these Co-inciding with the Horizontal-line, and having no Elevation or Depression, there is no Difficulty in placing them, when rightly made.

ALSO North and South Incliners or Recliners, being erect direct Dials in other Latitudes, are to be made as such and then placed in the Latitude proposed, with the given Reclination or Inclination, &c. which is easily intelligible to every Capacity.





SECTION XI.

How to make a Polar Dial.

IN making a Polar Plain, you have no more to do but draw a Circle, and divide it into 24 equal Parts for the Hours, and draw Lines from the Center of the Dial through these Divisions to the Edge of the *Dial*, which may be round, square or what Form you please, and placing 12 on that side towards the elevated Pole, put 11, 10, 9, &c. of the Forenoon Hours, and 1, 2, 3, &c. of the Afternoon Hours so far as you have Occasion, will be the true Hour-lines of a *Polar Dial*.

Example of a Polar Dial for Latitude 51 d. 32 m.

LET the Square A B C D be your Plain, bissect A B in *e*, and C D in *f*, and draw *ef*.
Plate 11. Also bissect B C in *g*, and A D in *h*,
Fig. 5. and draw *g h* perpendicular to *ef*; to cut each other in Q; then upon Q as a Cenetr, describe the Circle *r f t u*, and beginning at *r*, divide the Quadrant *r f* into six equal Parts, and each of the Quadrants in the Points * * *, &c. Lines drawn from the Center Q thro' these Marks, are the true Hour-lines in such a *Dial*.

Note, A *Polar Dial* to be placed under the *Pole*, ought to have all the 24 Hours upon it; but because a *Polar Dial* to be placed in any other Latitude is only a North Dial reclining equal to the Latitude of the Place, and because in Latitude 51 deg.

deg. 32 min. the Sun never riseth till after 3 in the Morning and always setteth before 9 at Night, it will be sufficient in this to insert the Hours from 4 in the Morning to 8 in the Evening.

THE Stile is only a Pin of Brasse, Iron, or the like, fixed in the Center Q, and placed perpendicular to the Plain of the Dial.



SECTION XII.

Of an Equinoctial Dial. Pl. 11. Fig. 6.

AN Equinoctial Dial is a South Recliner in North Latitude, or a North Recliner in South Latitude, equal to the Complement of Latitude, and is most properly done upon an oblong Plain, thus ;

AT a convenient Distance from the Edge of your Plain, draw the Line B C, and parallel thereto near the other Edge draw the Line D E, and through the Middle of these draw F G perpendicular to them, for the Hour-line of 12.

THEN upon either of the *Polar Scales* marked (*Pol.*) take the Distance from the Beginning of the Scale to I, and set that Extent from F, and also from G, both Ways to 11 and 1, on the Lines B C and D E. Again, Extend your Compasses from the Beginning of your Scale to II, and set that from F and G, both Ways upon the Lines B C and D E to 10 and 2 ; take also the Distance from the Beginning of the Scale to III, and set from F and G to 9 and 3, and in like manner take the Distance from the Beginning of the Scale to IIII, and set from F and G to 4 and 8. And lastly, take the Distance from the Beginning of the Scale

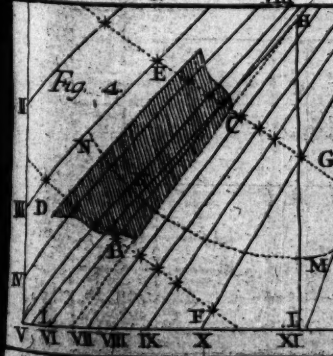
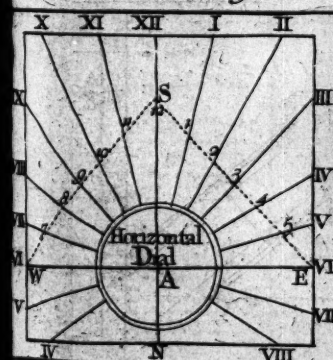
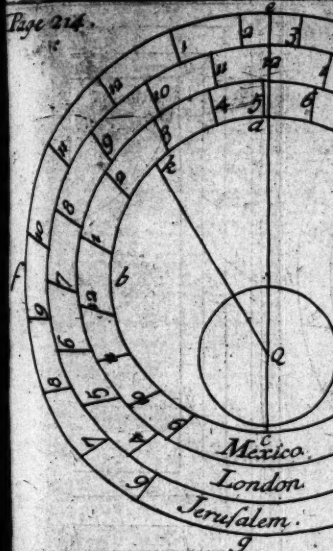
to V, and set from F and G to 7 and 5, (the Hour of 6 can never come into an Equinoctial Plain) then draw the Lines 77, 88, 99, &c. these are the true Hour-lines on that *Plain*.

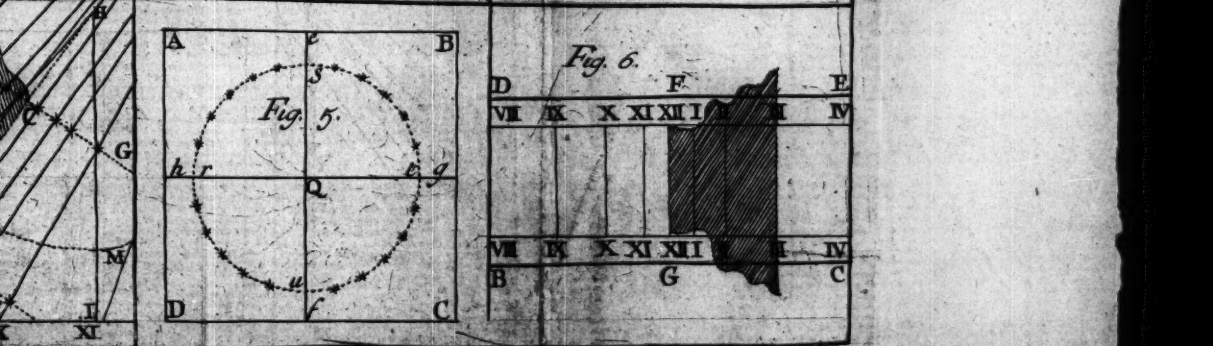
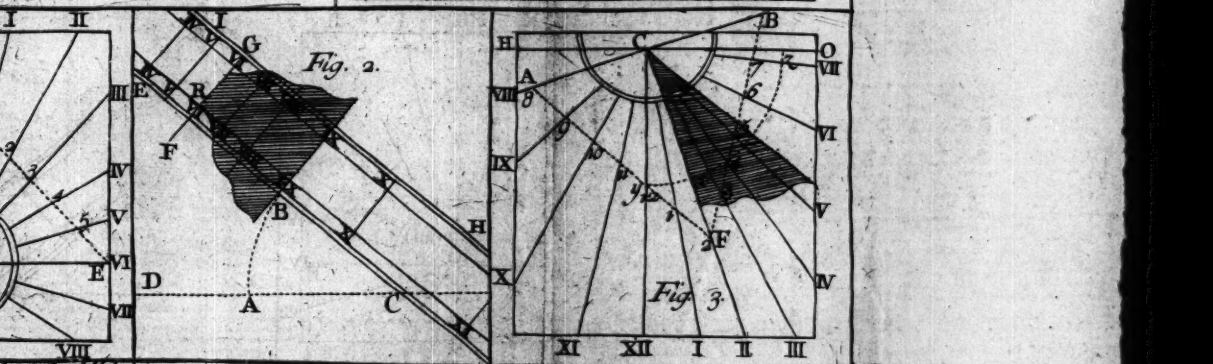
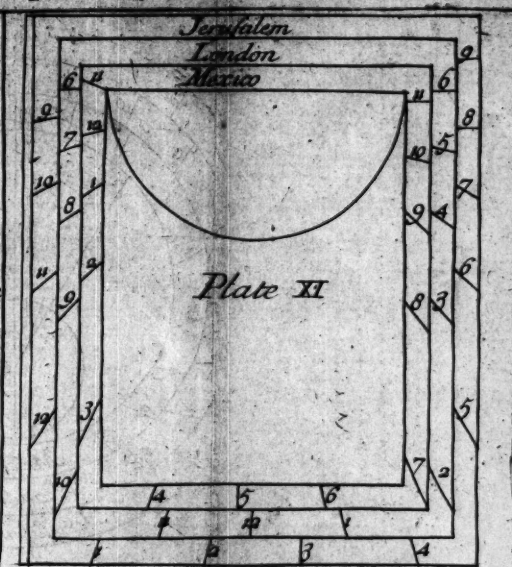
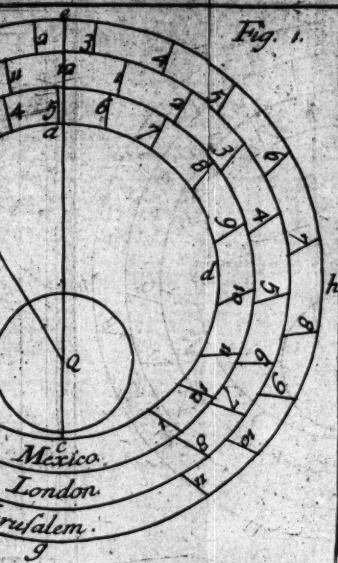
THE *Stile* may be a thin Plate of Brass, Iron, &c. and must stand upon the *Hour-line* of 12, perpendicular to the *Plain* of the Dial, its Top or Edge that casts the Shadow must be parallel to the *Hour-line* of 12, and its Height must be the Distance between the *Hour-lines* of 12 and 3, and then is your Dial finished.

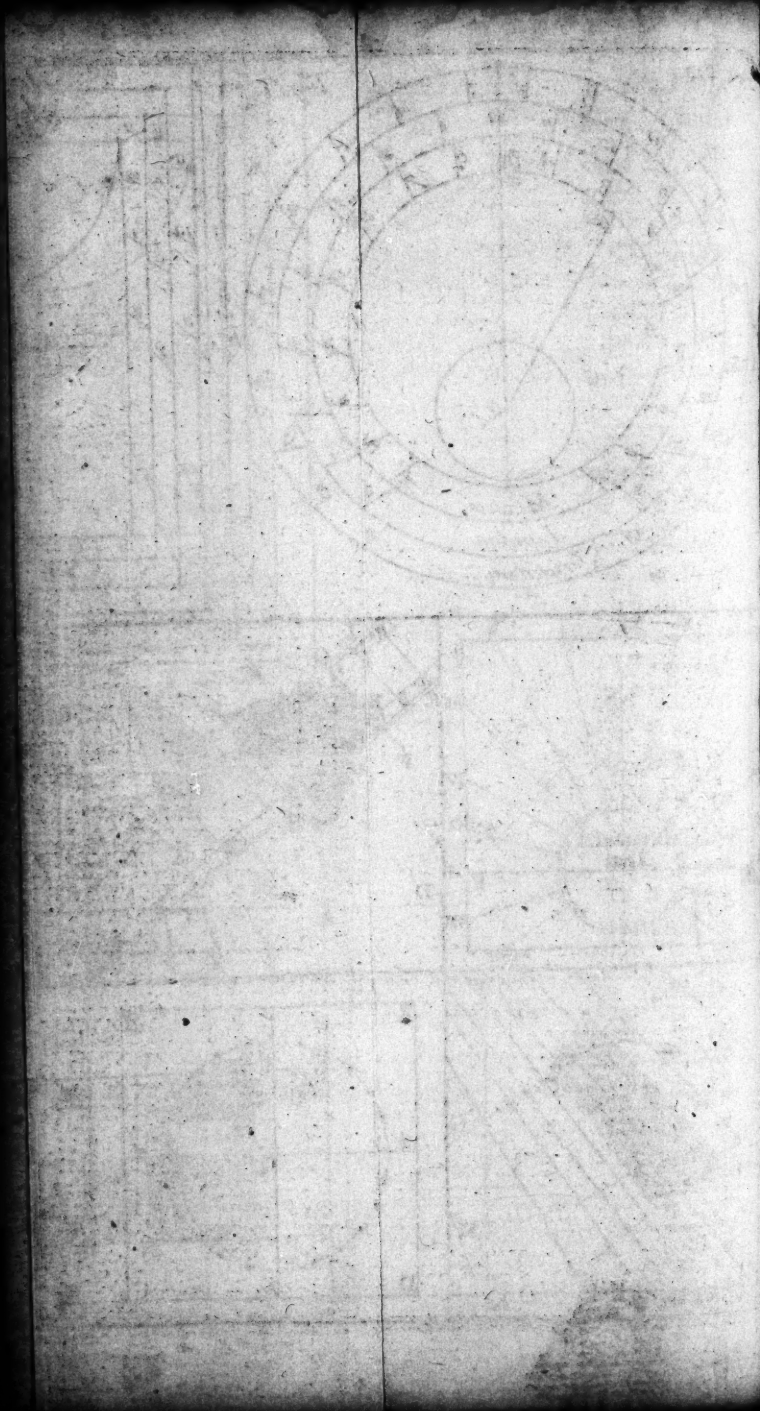
OR, the same may be performed by the Help of a *Sector*, if you make the intended Height of your *Stile* Radius, and at that Opening set the Tangent of 15, 30, 45, 60, and 75 from the 12 a Clock Line both Ways to 11 and 1, to 10 and 2, to 9 and 3, to 8 and 4, and to 7 and 5, as you were taught in making an East Dial, to set the same from the 6 a Clock Line to the Hours of 7 and 5, 8 and 4, &c. which is so plain, that I need not enlarge upon it.

NOTE, In this and all other Dials that shew the Hour by a *Stile* or *Gnomon*, you must allow for the Thickness of the *Stile*, imagining the Dial to be cut in two in the *Substile*, and the Parts drawn so far asunder as the Thickness of the *Stile*; for as it is impossible to make a *Stile* without some Substance in Thickness, it will follow that the Dial would be too slow, when the West-side gives the Shadow, and too swift when the East-side gives it, if the *Substile* do not possess a Space equal to the Thickness of the *Stile*, to contain all the Shadow of the *Stile*, when the Sun is just perpendicular to it.

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C H A P. XI.

Of Mechanick DIALLING.

Teaching how to make any Plain Dial either direct, declining, &c. without the Help of Mathematical Calculation, or any Instrument, except only a plain Ruler, and a Pair of Compasses.

ALTHOUGH the Varieties of Dialling before treated of (*viz. Geometrical, Arithmetical, and Instrumental*) might be thought sufficient, yet because this Book may come into the Hands of some that have not learned so much *Geometry* or *Trigonometry*, as to be capable to put those Directions in Practice, or cannot procure a Ruler with the Dialling Scales upon it (which is the Case of many *Masons, Carpenters, &c.* in the Country.) For the Sake of such I have added this Chapter, whereby any Person that can but read and write, will be able to draw a Dial upon any Plain, provided he can raise or let fall a Perpendicular, and draw a Line parallel to a Line given, &c. which is taught at the Beginning of this Book.



SECTION I.

How to describe the Hour-lines upon a Horizontal Dial.

I Shall, to avoid needless Repetitions, forbear to give any general Direct'ons, and fall directly upon an Example. Let it therefore be required to draw a *Horizontal Dial* for Latitude 51 deg. 30 min.

FIRST, Through the Middle of your Plain draw the Line A B for the Meridian, or 12 a Clock Line, and some where near the Middle of it, as at Q, cross it at right Angles with the Line 6 6, then with any Extent of your Compasses, and one Foot in the Center Q, with the other describe the Quadrant E B, which divide into 90 Parts thus; *First*, With the same Extent of your Compasses, with which you swept the Quadrant, and one Foot in B, set the other towards E, and there make a Mark, for that is 60 deg. then with the same Extent and one Foot in E, set the other towards B, making also a Mark, thus is the Quadrant divided into three equal Parts, each containing 30 deg. Divide each of these Parts again into three equal Parts, then each of these last Divisions into two equal Parts, each of which will be 5 deg. And lastly, divide each of these last into 5 Parts, so will the Quadrant be divided into 90 equal Parts or Degrees.

Now

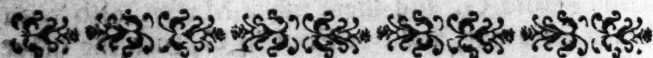
Now because the Latitude proposed is $51\frac{1}{2}$ degrees, count $51\frac{1}{2}$ of those 90 deg. from B towards E, which will reach to Z; then from the Center Q draw the Line QZ for the Stile; assume a Point any where at Pleasure, in the 12 a Clock-line, as at C, through which draw the Line LF parallel to the Line 6 6; this last Line we will for Distinction call the Tangent-line. Place one Foot of your Compasses in the Intersection of the Meridian and Tangent-line, as at C, and with the other take the nearest Distance to the Stile QZ, and keeping one Foot still in C, turn the other about till it cut the Meridian-line in D; then upon D as a Center, with the same Extent D-C, draw the Semicircle HCG, and draw the Diameter HDG parallel to LF, then with the same Extent, with which you draw the Semicircle, and one Foot in C, turn the other Foot both Ways towards H and G, and there make Marks, also with the same Extent, and one Foot in G, turn the other towards C, and where it falls upon the Semicircle make a Mark; then with the same Extent, and one Foot in H, turn the other towards C, and there also make a Mark, then is the Semicircle divided into 6 equal Parts; divide each of these Parts into two, and then it will be divided into 12 equal Parts; lay a Ruler from D, the Center of the Semicircle, over every one of these Divisions, it will cut the Tangent-line in the Marks * * *, &c. And *Lastly*, From the Center Q draw Lines through the Marks * * *, &c. in the Tangent-line, they shall be the true Hour-lines of the Dial.

If you desire to have the half Hours and Quarters, you must divide each of the 12 Divisions of your Semicircle into Halfs and Quarters, and transfer them to the Tangent-line, and from thence
from

from the Center to the Dial, as you did the Hour-lines.

THE Lines being thus drawn, place 12 at the Middle or Meridian-line, and proceed towards the right Hand with 1, 2, 3, 4, 5, &c. and towards the left with 11, 10, 9, 8, &c. and for the Hours of 4 and 5 in the Morning, and 7 and 8 at Night, they are found by continuing the Hours of 4 and 5 in the Afternoon, and 7 and 8 in the Morning, quite through the Center, as you see in the Figure.

THE *Stile* is to be a thin Plate of Brass, or the like, made in the Form of the Triangle B Q Z, to be erected perpendicularly upon the Line Q B, the Side Q B of the *Stile*, upon the Line Q B, and the Angular Point at Q, and then is your Dial finished.



SECTION II.

How to describe Hour-lines upon an Erect Direct South Dial. Plate 12. Fig. 2.

LET it be required to describe a South Dial for Latitude 51 deg. 30 min.

First, Through the middle of the *Plain* draw the Line A B, and at the upper End thereof, as at A, cross it at right Angles, with the Line 6 A for 6 a Clock, or an East and West Line; then with as large an Extent of your Compasses as your Plain will admit of, and one Foot in A, describe the Quadrant B C, which divide into 90 Parts or Degrees, as you were taught Sect. I. of which set

38, 30

38, 30 the Complement of the Latitude from B to E, and draw A E for the Stile, then assume a Point at Pleasure in the Line A B, as at F, thro' which draw the Line O F H, perpendicular to A B for a Tangent-line; with one Foot of your Compasses in F, with the other take the nearest Distance to the Stile A E, and keeping that Foot still in F, turn the other till it cut the Meridian-line A B in G, then letting that Foot rest in G, with the other describe the Semicircle I F L, which divide into 12 equal Parts, as you were taught to divide the like Semicircle in *Sect. 1.* of this Chapter. Lay a Ruler from G, over the equal Divisions in the Semicircle, and it will cut the Tangent-line O F H in the Marks * * *, &c. Lastly, Draw Lines from the Center A through the Marks * * *, &c. in the Tangent-line, they shall be the true Hour-lines of the Dial.

HAVING thus finished the Hour-lines, place 12 at the End of the Line A B, and (supposing the Dial to face the *South*, and your Face towards it) proceed with 1, 2, 3, &c. towards the right Hand, and with 11, 10, 9, &c. towards the left Hand, always observing that a *South* Dial can never contain any more Hours than those from 6 in the Morning, to 6 in the Evening.

THE *Stile* may be a Plate of Brass, or the like, in Form of the Triangle, B A E, the side B A to be set upon the Line B A perpendicular to the Plain of the Dial, the Angle of the *Stile* being just at the Center or Point A of the Dial, and then is your Dial finished.

SECT.



SECTION III.

Of an Erect Direct North Dial.

THE *Erect Direct North Dial* is made by the same Rules as a *South Dial* is made, the Hour-lines and Stile being the same, only in a North Dial the Stile points upwards, making also an Angle with the Plain of the Dial, equal to the Complement of Latitude; and for the rest observe.

1. To put no more Hours than are of Use, as at *London*, 4, 5, 6, 7, 8, in the Morning, and 4, 5, 6, 7, 8, in the Evening, the Sun never shining on a North Plain at any other Hours.

2. THAT (though the Divisions are the same) the Hours, which on the *South Dial* are marked 6, 7, 8, in the Morning, must on the *North Dial* be marked 4, 5, 6, in the Morning; and the Hours of 4, 5, 6, in the Afternoon, must be 6, 7, 8, in the Evening.

3. BECAUSE upon a *South Dial* you never draw any Hour before 6 in the Morning, or after 6 in the Evening; but the North Dial (at *London*) takes in 4 and 5 in the Morning, and 7 and 8 in the Evening: Therefore to supply that on the North Dial, you need but continue the Hour-lines of 4 and 5 in the Afternoon quite through the Center, and that gives you the Hour-lines of 4 and 5 in the Morning on the opposite Side, and the Hour-lines of 7 and 8 also continued, gives you the Hours of 7 and 8 in the Evening.

4. As

4. As for what Hours are necessary to be put upon a *North Dial* in any other Latitude, I shall refer you to the Table (*Page 190.*) with its Explanation immediately following; there you have the Length of the *Longest Day* in all Latitudes, whereby you may find the Sun's Rising and Setting in all Latitudes, and consequently know what Hours in the Morning or Evening are proper to be put upon a *North Dial*, it being superfluous to put on the Hours before Sun-rise, or after Sun set.

5. If a *North Dial* for any given Latitude be required to be made, take a Sheet of oyl'd-Paper, and proceed in all Respects by the foregoing Directions to make a *South Dial* for the Latitude proposed, (only you may save the Labour of working for the Hours that you know will be of no use) which done, turn the Paper over, taking that End towards you which was farthest from you, and you will see through the Paper the true *North Dial* required, which I think will not need any further Explanation.



SECTION IV.

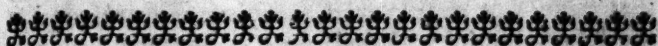
How to describe an Erect Direct East Dial.

Plate 12. Fig. 3.

HAVING prepared your Plain W X Y Z, whether Wood, Brass, &c. Draw towards one Side of it the Line A B parallel to W Z, and in that Line chuse a convenient Point towards the upper End thereof, as C, upon which as a Center, with any Extent of your Compasses describe the Arch

Arch D E, upon which from E, set off the Complement of Latitude, which in this Example we will suppose to be Latitude 54 deg. whose Complement to 90 is 36, set off therefore 36 deg. from E to D, and draw D C for the *Axis* of the World, then cross this Line at right Angles with the Line C F, drawing C F both Ways to the Edges of the Plain; chuse any convenient Point in the Line C F, as at 6, from which draw the Line 6 6 parallel to C D for the Substile and Hour-line of 6, (which in *East* or *West Dials* are always the same) continue the Line 6 6 at Pleasure, as to G, with the Extent from G to the Line C F, keeping one Foot of the Compasses in G, with the other describe the Semicircle Q R, which divide into 6 equal Parts both Ways from the Line G 6, and laying a Ruler from G over these Divisions, it will cut the Tangent-line C F in the Points * * *, &c. from every one of which Marks draw Lines parallel to C D, they shall be the Hour-lines required, which (beginning at 6) must be numbred upwards with 5 4, and downwards with 7, 8, 9, 10, 11, the Hour of 12 can never come into an East Plain, because at that Hour the Sun being upon the Meridian, is just upon the Edge of the Plain.

THE Stile is a thin Plate to be fixed upon the Hour-line of 6 perpendicular to the *Plain* of the Dial, being from End to End, equally of the Height of the Line G 6, the Extent with which you drew the Semicircle.



SECTION V.

Of an erect direct West Dial.

AN erect direct West Dial is described in all respects by the Rules given for the *East Dial*, only appear differently in two Particulars.

1. THE *East Dial* is elevated towards the Left Hand, but the *West Dial* is elevated towards the Right Hand, as the *East Dial* would appear, if seen through the Paper, the Divisions being also exactly the same.

2. WHEREAS the *East Dial* contains the Forenoon Hours, and is numbred from the upper Part downwards, with 4, 5, 6, 7, 8, 9, 10, 11, the *West Dial* contains the Afternoon Hours, and is numbred from the lower End upwards, with 1, 2, 3, 4, 5, 6, 7, 8, the Stile being the same, and standing upon the Hour line of 6 in both.

For the Figure of a West Dial, see Plate 3. Fig. 2.



SECTION VI.

How to describe the Hour-lines, &c. upon an Erect South (or North Dial) declining East.

ALTHOUGH we have given Directions (Chap. 2. Page 34.) for finding the Declination of any Plain, yet these Directions requiring some Knowledge in Astronomy previous to the Practice of them,

them, and this being designed for the Use of those that have not acquired a sufficient Knowledge in the Mathematicks, I shall give a Method, whereby (mechanically) to take the Declination of any Plain, as followeth,

TAKE a fine Board of Wainscot, or the like, of about a Foot square, or more or less at Pleasure, and plain it very Fine, or else paste a Sheet of strong white Paper very smooth, on one Side of it, as you see in the Figure, the Board represented by A B C D. From the middle of the *Plate 12.* Side A B, erect the Perpendicular x y *Fig. 4.* z, and in the middle thereof, as at y, place one Foot of your Compasses, and with the other point at several different Extents, draw the *Concentrick Circles*, as you see in the Figure, (it matters not what Distance they are from each other, or whether they be equally distant among themselves) this done, erect a small Pin of 3 or 4 Inches in Length, exactly perpendicular in the Center of the Circles, and then is your Instrument ready for use.

Note, If you are doubtful of your Performance in erecting the Pin exactly perpendicular, you may place the Pin before you make the Circles, and then with one Foot of your Compasses in the middle of the Top of the Pin, with the other describe the Circles as before, and then you are sure that the Middle of the Top of the Pin, where you placed your Compasses, is perpendicular to the (supposed) Center of the *Circles*, whether the Pin be perpendicular to the Plain, or no, and then draw a Line perpendicular to the Side A B, and to cut each *Circle* exactly in two Parts, proceed to make use of the Instrument, as followeth.

PLACE

PLACE the Instrument exactly parallel to the Horizon, with the side A B against the Wall or Plain, whose Declination you desire to know, and then about 7, 8 or 9, in the Morning, (when the Sun is clear of the Refraction of the Horizon, and before 10 or 11 a Clock, because then the Sun rises but slowly) observe which of the *Concentrick Circles* the Top of the Shadow of the Pin cuts, and where it cuts it, and there make a Mark. This done, let your Instrument stand un-removed till the Afternoon, and then wait till the Top of the Shadow cuts the same *Circle* again (for all the Time between the Observations the Top of the Shadow will cut the inner Circles) and there where it cuts the same *Circle* make a Mark, then divide the Space between these two Marks into two equal Parts, and in the exact Middle between them, on the same *Circle*, make another Mark, for that shall be the true North Point; then (as you were taught in *Sect. 1.* of this *Chapter*, or by the help of a Line of *Chords* on a Sector, if you have it) find how many Degrees are contained between the last Mark found, and the Point where the Line *x y z* cuts the same *Circle*, for that is the Declination of the *Dial*; and if the Mark last found falls on the East-side of the Line *x y z*, the Dial declines East, if on the West-side, it declines West, but if the Line be just in the Middle between the two Marks, it is a true South Plain, and hath no Declination at all.

Note, In your Morning and Afternoon Observation, as above, you need not regard the Hour of the Day, nor the Sun's Altitude, so as to know what they are, but only observe the two Points, where the Top of the Shadow cuts the same Circle as before, and if at your first beginning in the Morning, the Top of the Shadow doth not fall exactly

exactly upon a *Circle*, wait till it doth; for as the Sun rises the Shadow passeth from one *Circle* to another, *viz.* from the greater to the lesser, and the contrary at his falling in the Afternoon.

HAVING thus found the Declination of the *Plain*, your next Work is to proceed to make the Dial, which for an Example, shall be a South Dial, declining East 40 deg. for Latitude 54 deg. 00 min.

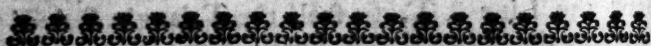
IN performing the Work of this one Dial, you have also made three more, as is farther demonstrated Page 50 and 51, and *Plate 3. Fig. 4.* to which I shall refer the Learner for farther Instruction in that Variety: But of these four the South declining East is that in the lower Part of the Projection, for making of which, first, towards the upper part of your Plain, draw the Line E W for the East and West, or Horizontal-line, in which chuse a Point, as at A, for the Center of your Dial, upon which describe the Semicircle Z M E. Through the Point A, in the Horizontal-line E A W, and at Right Angles to it draw the Line A M, which divides the Semicircle Z M E into two Quadrants, of which that towards the left Hand, *viz.* the Quadrant A Z M, serves for our present Purpose, because the Dial declines East, and consequently the Substile, &c. falls in that Quadrant: Therefore, set 40 deg. (the Plain's Declination) from M towards Z, upon the Arch M Z, and through the Point where that falls, and from the Center A, draw A D the Line of Declination, then set the Complement of Latitude, *viz.* 36 (because the Latitude is 54, and its Complement to 90 is 36) from M the same Way upon the same Arch, and thro' the Mark where that falls, and from the Center A, draw the polar Line A P, then

then assume a Point at pleasure in the *Horizontal-line* W A E, at a convenient Distance from A, as at B, and from thence draw a Line parallel to A M, to cut the polar Line A P in P. From P draw a Line parallel to the *Horizontal-line* W A E, as the Line P C. Take the Distance A B upon the *Horizontal-line*, and set on the Line A D from A to D, and through D draw a Line parallel to A M, to come into the *Horizontal-line* at R, and continue it through D till it cut the Line P C in S, a Ruler laid from A to S, and the Line A S drawn thereby, is the *Substile* of the Dial. Then at the Point S erect a Perpendicular to the Line A S, as the Line S T. Set the Distance R D from S to T, and draw the Line A T, so shall the Triangle S A T represent the *Stile* of the Dial; for a Triangular Plate in that Form, erected perpendicularly upon the *Substile* A S, shall by its upper side A T cast a Shadow to the Hour of the Day, when the Hour-lines are drawn, which is the next Thing to be done.

For drawing the Hour-lines, assume a Point in the *Substile* at pleasure, through which, and at Right Angles with the *Substile*, draw the Tangent-line F F as long as you can, and setting one Foot of your Compasses, where the Tangent-line cuts the *Substilar*, take with the other the nearest Distance to the *Stile*, or Line A T, and with the same Extent, one Foot remaining in the Point of Intersection, with the other find the Point \mathcal{A} in in the *Substile*, and with the same Extent (one Foot resting in \mathcal{A}) describe the Semicircle m n; this done, lay a Ruler from \mathcal{A} , (the Center of the Semicircle) to the Point where the Tangent-line E F cuts the Meridian A M, as at O; begin at O to divide the Semicircle into 12 equal

equal parts, at every one of which make a Mark. Then lay a *Scale* from \AA , the Center of the *Semicircle*, over the said Marks, it will cut the *Tangent-line* in the Marks * * * *, &c. And lastly, lay a *Scale* from A, the Center of the Dial, over these Marks * * * *, &c. in the *Tangent-line*, and Lines drawn thereby will be the true *Hour-lines* of that Dial.

In this, as in a *South Dial*, the Hour of 12 is at the *Meridian*, or middle Line of the Dial, and the rest numbred forwards with 12, and backwards towards the left Hand with 11, 10, 9, 8, 7, 6, 5, 4, as you see in the Figure.



SECTION VII.

Of Dials declining from the South Westward. Plate 12. Fig. 5.

FIRST, Draw the *Horizontal-line* W A E, and upon the Point A in the middle of it, as a *Center*, describe the *Semicircle* Z M E, as you see taught in the last Section for Dials declining from the South Eastward, and draw A M perpendicular to W E, which will divide the *Semicircle* Z M E into two *Quadrants*; and as in the *South East declining Dial*, the *Quadrant* A Z M was of use, so in this the *Quadrant* A E M must be made use of, because in it the *Substile* and other Parts of the Work necessarily fall, and there is no Difference in the Operation, only instead of setting from A or M, &c. to the left Hand in the last, you set from

from A or M, &c. to the right Hand in this ; so that if the last had been drawn upon oyl'd Paper, or any other transparent Thing, so as to be seen through on the back side of the Paper, it would be exactly a South Dial declining West, as far as the other did East, and for the same Latitude only, the 11 must be 1, and the 10 must be 2, and so in the rest, and the North Decliners are also deduced therefrom, as is taught at large Page 50 and 51, before-mentioned.



SECTION VIII.

Of East or West Reclining or Inclining Dials.

ALTHOUGH we have given Directions (Page 125,) for reducing East and West Recliners for any given Latitude to new Latitudes and new Declinations, and so may be performed by the Directions given in Sect. 6 and 7. of Mechanick Dialling, yet I shall here, for the Learner's Improvement, shew how they may be done *Mechanically*, without any such Alteration, whether they be East or West, Reclining or Inclining.

It will be necessary first to premise, that East and West Recliners have their Centers near the Bottom, and in this the Incliners of both Sorts have their Centers near the Top : The West Recliner and East Incliner should have their Centers toward the right Hand, and the West Incliners and East Recliners have their Centers most commodiously towards the left Hand : Therefore,

SUPPOSE I would make an East Dial to recline 35 deg. for Latitude 54 deg.

L

HAVING

HAVING prepared my square Plain W X Y Z, I consider by the foregoing Rules
Plate 12. where I may most conveniently chuse
Fig. 6. my Center; and I find first, that all Recliners both East and West, have their Centers at or near the Bottom; and secondly, I find that East Recliners should have their Centers most towards the left Hand; therefore at the Bottom of the Square W X Y Z, draw the Line S N for the Meridian, in which, not at the Middle, but rather towards the left Hand, as at A, I chuse the Center, and from A perpendicular to the Line S N, draw A E; also with one Foot of your Compasses in A, describe the Quadrant T U, and set off 45 Degrees (the Reclination of the Plain) from T towards U, and through that Point in the Quadrant where the 45 Degrees end, and from the Center A draw the Line A O. Also set off upon the same Quadrant from T, the Complement of Latitude 36 Degrees, and thro' the Point where that reaches upon the Quadrant, and from the Center A draw the Line A P; then in the Meridian Line N S chuse a point at pleasure, as B, and from that Point draw a Line parallel to A E, which will cut the Line A P in P. From that Intersection at P, draw a Line parallel to the Meridian-line S N, to come to the Perpendicular A E in C; and also from the Line A O in O, take the Distance A O, and set upon the Perpendicular A E, from A to E, and draw E G parallel to S N, which will cut B P continued in G; set also the Distance C O from A to Q, upon the Line A O, and draw the Line Q R parallel to B P; take also in your Compasses the Distance A R (from the Line S N) and set it off upon the Line G B, from G to S, a Line drawn from A to S shall be the *Substile* of the *Dial*. Draw S M

per

perpendicular to A S, and take in your Compasses the Distance Q R, and set from S to M, and laying a Ruler from the Center A to M, a Line drawn by it shall be the stilar Line, the Triangle A S M representing the *Stile*, which being erected perpendicular to the Plain of the Dial upon the *Substile* A'S, shall give the Hour by the Shadow of its upper Edge, which will be parallel to the Axis of the World.

FOR drawing the Hour-lines, chuse a Point at pleasure in the Substile A S, and through that at right Angles draw the Tangent-line I K as long as you can, and with one Foot of your Compasses in the Point where the Tangent-line I K crosses the *Substile* A S, take with the other the nearest Distance to the *Stile* A M, which done, (keeping the other Foot yet in the aforesaid Intersection) turn the Compasses about, till it cuts the *Stile* A S, as in \AA , and fixing that Point in \AA , with the other at the same Extent describe the *Semicircle* I n; draw a Line from \AA the Center of the *Semicircle*, to the point where the Tangent-line I K, cuts the Perpendicular, and observe where it cuts the *Semicircle*, and there begin to divide it into 12 equal parts. A Ruler laid from \AA over the equal Divisions of the *Semicircle*, will cut the Tangent-line I K unequally in the points * * *, &c. And Lastly, a Ruler laid from the Center A to these Marks * * *, &c. in the Tangent-line, and Lines drawn thereby, shall be the true Hour-lines required.

THE Line S N being the Meridian and Hour-line of 12, you must place 12 at the End of it, and the rest 11, 10, 9, 8, 7, 6, 5, 4, as you see in the Figure

In drawing this, you have in Effect drawn three more; as,

1. If it was turned upside down, the same side is a West Dial inclining 45 deg. only the Hours are for the Afternoon, as for 11 put 1, for 10 2, and then the *Substile* will consequently be as much on the right Hand of the Perpendicular, as now it is on the left.

2. If it was drawn on oyl'd Paper, the back-side would be a West Dial reclining 45 deg. only the Figures instead of 12, 11, 10, 9, &c. must be 12, 1, 2, 3, &c.

3. If the Meridian-line S N be turned upwards, the Back-side will be an East Dial inclining 45 d. and the Figures, as they are, only the Substile must be as far to the left Hand of the Perpendicular A E, as now it is on the Right.

SECTION IX.

Of Direct South or North Plains Inclining or Reclining.

IT is needless to give any Directions about direct North or South Reclining or Inclining Dials, because they are erect direct North or South Dials in some other Latitude; and how to reduce them to such, you are fully taught in Sect. 5. of *Instrumental Dialling*, Page 192, 193, 194, and when they are reduced to direct North Dials in another Latitude, they are made by the Directions given, page 218, and 220, to which (to avoid Repetitions) I shall refer the Learner in this Case.

SECT.



SECTION X.

To describe the Hour-lines upon a South or North Inclining, Declining, or Reclining Plain.

THESE Dials, though different in Situation, are the same as to the Method of Projection; for the South Inclining Declining, and North Inclining Declining, as also the South Reclining Declining, and likewise the North Reclining Declining, are the same, only differently placed, and are to be projected by the following Rules.

NOTE, You are taught in *Sect. 10. of Instrumental Dialling, Pag. 205.* how to reduce (*Plate 12. Fig. 7.*) any Declining Reclining Dial, for any given Latitude, to a new Latitude and new Declination, where it will be an upright declining Plain; which being done, you may proceed according to the Directions given in *Sect. 6. of Mechanick Dialling Pag. 223 to 228;* but because that requires *Trigonometrical Calculation* for finding the new Latitude and new Declination, (which we suppose some *Mechanicks* are not capable of) I shall shew how it may be done without any *Trigonometrical Operation* whatsoever.

I shall instance in a *South Dial* declining East 26 deg. and inclining 36 deg. for Latitude 51 d. 30 min.

DRAW a Line on the upper-side of your Plain parallel to the *Horizon*, which mark with E W viz. (because the *Dial* faceth to the *Southward*) put E at the right Hand for East, and W at the left

left Hand for West ; assume a Point in the Line E W, as at A, for a Center, upon which, with any Extent of your Compasses, (the longer the better) draw the Quadrant x y, and through x draw the Line A x X perpendicular to W E ; divide the Quadrant into 90 Degrees, as you are taught in *Sect. 1.* of this Chapter, *Page 216.* or by a Line of Chords (the making of which I shall shew hereafter) which is much more expeditious, and upon these Degrees of the Quadrant, set from x the Complement of Latitude $38\frac{1}{2}$ deg. the Declination 26 deg. and the Inclination 36 deg. making Marks in the Quadrant where these Degrees shall fall, and through these Points in the Quadrant, and from the Center A, draw the Lines A b, A c, and A d. Then chuse a Point in the Line E W, towards the Quadrant, as at B, from which draw a strait Line perpendicular to E W, or parallel to A X, as the Line B P, to cut the Line A d (the Line drawn from the Center A through the point where the Complement of Latitude reaches in the Quadrant) in the point P, and thro' that Interseccion at P draw the Line P C parallel to W E, which will cut the Line of Inclination A c in O. Take in your Compasses the Extent A O, and set on the Line A x from A to F, and through F draw F G parallel to P C ; then take in your Compasses the Extent C O, and set it on the Line A X, from A to L, and draw L D parallel to W E, to cut the Line of Declination A b in D. Set the Distance A B from A to V, upon the Line of Declination A b, and from V draw V K parallel to W E, to cut the Line A X in K. Take in your Compasses the Extent V K, and set off upon the Line G F, (but on the contrary Side of the Perpendicular) from F to M, and draw M N parallel to A X, to cut the Line W E in the point N. Then

N. Then because the Plain is a South *Incliner*, (or if it had been a North *Récliner* it had been the same) take in your Compasses the Distance LD , and set upon the Line FG , from F to H , for a Meridian-line, or the Hour-line of 12; take in your Compasses the Distance AL , and placing one Foot in K , extend the other to the Point X ; then take the whole Distance AX , and set upon the Line of *Inclination* Ae , from A to Q , and from Q draw QR parallel to BG , to cut the Horizontal-line WE in R ; take in your Compasses the Extent AR , and with one Foot in M , extend the other in the Line MN to the Point S , and draw the Line AS for the Substile, and draw ST perpendicular to AS , and upon the Line SM set the Distance QR from S to T , and draw the Line AT for the Stile, so shall the Triangle AST represent the Stile to be erected perpendicular to the Line AS , and to stand upon that Line, the Side AT being parallel to the Axis of the World, and its Shadow upon the Hour-lines determining the Hour of the Day.

FOR drawing the Hour-lines upon this Dial, chuse a Point in the Substile AS , and through that Point, and perpendicular to AS , draw the Tangent-line Eg to cut the Substile AS in the Point h , take the nearest Distance from the Point of Intersection at h to the Stile AT , and keeping one Foot in h , turn the other about to the Point \mathcal{A} , in the Substile AS ; then keeping that Foot in \mathcal{A} , with the other draw the Equinoctial Circle to touch the Tangent-line; then lay a Ruler from \mathcal{A} the Center of the Equinoctial-line, to the Point where the Tangent-line cuts the Meridian-line AH , as in the Point \odot , and observe where that Ruler cuts the Equinoctial Circle, and from that Point begin to divide the Semicircle into 12 equal Parts,

as you were taught, *Page 217.* and then, as you have been formerly taught, lay a Ruler from the Center of the Equinoctial at Æ over the equal Divisions in the Circle, and observe, where it cuts the Tangent-line, as in the Points * * *, &c. And lastly, Lines drawn from the Center A thro' the Marks * * *, &c. shall be the true Hour-lines of that Dial.

FOR numbring the Hours, place 12 at the Meridian-line at H, and 1, 2 towards the right Hand, and 11, 10, 9, &c. towards the left Hand as far as the Hours extend.

Note, It is best in drawing this or any other Dial, to draw all the preparative Lines with Charcoal, or Black Lead, or the like, that they may be taken clean out, when you have put on the Hour-lines, and such other Furniture, as you think fit to put upon your Dial.

I might proceed to shew the Method of making Inclining Dials declining from the South-westward, as also North Recliners declining East and West, but they being all, (with a little Consideration) included in this, I shall only for the making of them give these general Rules.

1. AN Incliner declining from the South-Eastward, is what we have just now spoke of.

2. THE Incliner declining to the South-westward, is done by the same Directions, only the Quadrant which in the East Decliners is on the right Hand Quarter below the Horizon, must in the West Decliners, or those that decline from the South-westward, and also incline, be in the left Hand Quarter below the Horizon or Line W E, which may be best conceived by supposing this Dial to be drawn on oyl'd Paper, and looking through the Paper, that which on the right Side of the Paper was an inclining Dial declining from
the

the South-Eastward, will, (looking thro' the Paper) be an inclining Dial declining from the South Westward, &c.

3. A North declining East Recliner is the same of a South declining East Recliner, only the Horizontal-line W E must be at the Bottom of the Dial, and the Quadrant described thereon upon the Center A, must be above the Line E W, and towards the left Hand, and may be represented by a South declining East Recliner turn'd Bottom upwards with the same Side towards you as before.

4. A North declining West reclining, is the same with a South declining West inclining, only (as before) the Horizontal Line E W must be at the Bottom, together with the Center of the Dial, and the Quadrant must be above the Line, and towards the right Hand, and may be represented by the Dial already described, if imagin'd to be done upon oyl'd Paper, and seen through being turned Bottom upwards; but of this see more, *Chap. 27. Page 110 and 111.*

Note, The Hours on the North Dials must be numbred the contrary Way to those of the South Dials, and for what Hours to put upon any North Dial, whether declining, reclining, &c. See *Chap. 1. Sect. 10. Page 189.*

I have not drawn the Hour-lines in the Dial now described, lest it should too much confuse the Scheme, it being easy to imagine, where they will fall, when drawn from the Center A thro' the Marks * * *, &c. in the Tangent-line.



SECTION XI.

A very plain and easy Way to make a Dial, that shall give the true Hour by Reflection on a Cieling, where the direct Beams of the Sun can never come, and shall represent the Sun's Motion as true and regular within the House, as his natural Motion is without, provided the Window open to the Southward, or so that the Sun may shine in or near it.

TAKE a piece of clear Looking-glass, about three Quarters of an Inch broad, and fix it in a Window that looks to the Southward, (the nearer the Out-side of the Window that it stands, the longer the Sun will shine upon it, and therefore it would be better to make some Conveniency to place it upon, quite without the Window, that the Sun may shine upon the Glass as long as it shines upon the Wall) and take care to place your Glass very exactly parallel to the Horizon, for if you mistake in that, you throw all the Work amiss. This done, hold a Thread with a Plummet exactly over the Glass, and observe where the Shadow of the Thread falls upon the Floor exactly at Noon, and there draw a Line quite cross the Floor as far as you can, for this will be a true Meridian, or North and South Line; but if you have the Opportunity of a good Clock, Watch, or Dial, you may find the true North by the Directions given, Page 224, and 225. and having by any Means found the true North from the Glass, and thereby described a Line upon the Floor, or (which is the same)

same) stretch'd a Thread directly North from the Glass; take a Thread and Plummert, (the Plummert having its lower End brought to a Point) and holding your Hand up against the Cieling, with the Thread in your Hand, and the Plummert playing freely, move your Hand to and fro, till the Point of the Plummert rest over or upon the Thread or Meridian-line before found, and there where the upper End of the Thread toucheth the Cieling, make a Mark. Do the same at the other End of the Thread or Meridian-line upon the Floor, and make another Mark upon the Cieling; then with a Carpenter's Line, or a strait Ruler, draw a Right-line between those two Points, which will be a true Meridian, or North and South Line, upon the Cieling. Then because the Sun's Meridian Altitude, when in the Equinoctial, is equal to the Complement of Latitude of the Place, and because the Angle of Reflection is always equal to the Angle of Incidence, viz. a Line imagined to be drawn from the reflected Spot upon the Cieling, to the middle of the Glass, makes always the same Angle with the Plain of the Glass, that a Line drawn from the Sun to the same would do, it will follow, that the Equinoctial must cross the Meridian just in that Point that makes an Angle with the Plain of the Glass equal to the Complement of Latitude of the Place, which Point in the Meridian may be thus found.

CAUSE one Person to hold a Thread exactly upon the Middle of the Glass, and stretching it tight, hold the other End up to the Meridian upon the Cieling, to make (as near as you can guess) an Angle with the Horizon equal to the Complement of Latitude; and holding it there, apply the Side of a Gunter's Quadrant to it, if it make too

great an Angle, (keep that End fast upon the Glass, and) slip a little more of the Thread out of your Hand, and so moving gently to and fro, find where it makes just the required Angle (as suppose of $38\frac{1}{2}$, if it be for Latitude $51\frac{1}{2}$ deg.) there make a Mark in the Meridian upon the Cieling, for there the Equinoctial must cross it; therefore through that Mark draw a Line cross the Cieling at right Angles, with (or perpendicular to) the Meridian, to represent the Equinoctial.

Note, It may be as well to put the Thread thro' the Holes in the Sights of the Gunter's Quadrants, and letting the Plummet play freely, proceed as before,

KEEP your Thread still fast, one End in the middle of the Glass, and the other End in the Point, where the Equinoctial cuts the Meridian in the Cieling, turn your Quadrant with its Center to the Center of the Glass, and its Side or Semi-diameter exactly along by the Thread, propping or otherwise securing it that it may not stir, then (because every 15 Degrees of the Equinoctial is an Hour of Time) remove the String 15 Degrees of the Quadrant, and observe where it cuts the Equinoctial, when stretched to it, and there make a Mark; do the like for the next Hour, removing the Thread to 30 Degrees, and stretching it to the Equinoctial, make a Mark, where it cuts it; do the like at 45 deg. 60, &c. as far as you can, which done, remove your Quadrant to the other Side of the Meridian, and setting of 15, 30, 45, 60, &c. Degrees, make Marks on the other Half of the Equinoctial, and so you have the Points where the Hour-lines intersect the Equinoctial, which are to be numbred with 12, where the Meridian cuts the Equinoctial, and from thence

thence Eastward with 1, 2, 3, &c. and Westward with 11, 10, 9, &c. as far as the Room extends.

Note, You may continue the Equinoctial down by the Sides or Walls of the Room, as well as upon the Cieling over it; if you continue the Quadrant at the aforesaid Elevation, and continue the Equinoctial down the Wall, so as that it may just coincide with the Plain of the Quadrant, which may be done by continuing the Thread parallel to the Plain of the Quadrant till it touch the Wall; and though the Wall be never so irregular, the Equinoctial may be by this means continued, and the Hours upon the Wall as well as the Cieling may be found by every 15 deg. removing the Thread.

As for the *Hour-lines*, they are to pass thro' these several Points found in the *Equinoctial* by the aforesaid Means, but they must not cut the *Equinoctial* at *right Angles*. To find the Center, or Point of Interfection of the Hour-lines will be difficult, because it falls without the Room in the Air; for as the Equinoctial is elevated equal to the Complement of Latitude, so the Pole is elevated equal to the Latitude; and as the elevated Pole is to the Northward from us, and a Line suppos'd to be drawn from it to the Center of the Glass, will make with the Horizon an Angle equal to the Latitude of the Place, so the reflected Axis of the World shall describe an infinite Line in the Air to the Southward, making with the Horizon the same Angle.

BUT because the Pole or Center of the Equinoctial falls without in the Air, it is not so easily accessible for drawing the Hour-lines; therefore to remedy that Inconveniency, observe by the

the Directions given, (Sect. 1.) For drawing an Horizontal Dial, what Angle every Hour-line makes with the Meridian, and in this Case, they must make an Angle equal to the Complement of the same Angle with the Equinoctial. As for Example.

SUPPOSE I would make an Horizontal Dial for Latitude 51 Degrees, 32 Minutes North. I shall find by the Directions given, Sect. 1. that the Hour-lines make Angles with the Meridian, as followeth.

			d.	m.
12			0	0
11	1	makes an Angle of	11	50
10	2		24	20
9	3		38	3
8	4		53	35
7	5		71	6
6			90	0

THESE are the Angles that each Hour-line makes with the Meridian; their Complements to be made with the Equinoctial, are,

For

For

12	
11	1
10	2
9	3
8	4
7	5
6	

The Angle with
the Equinocti-
al is

90	0
78	10
65	40
51	57
36	25
18	54
0	0

THEREFORE, if through the several Points found in the Equinoctial for the Hours, you draw Lines to make the last before-mentioned Angles with the Equinoctial, they shall be the several Hour-lines required, and the Sun shining upon the Glass shall reflect the Light at any Time of the Year upon the Hour of the Day.

Note, What is said here of the Angles which the Hour-lines make with the Equinoctial, is meant while the Equinoctial is continued upon the Cieling parallel to the Horizon, and not with Respect to its being continued down the Wall.



SECT.



SECTION XII.

How to make a Line of Chords, whereby any Number of Degrees may easily be set off upon any Circle, without the fore-mentioned Trouble of dividing it.

DESCRIBE a Semicircle, and divide the Circumference of it exactly into two equal Parts at c, then divide either of the Quadrants (as suppose b c) into 90 equal Parts, as you are directed in the first Section of *Mechanick Dialling*, and you may draw the Line b c. Then upon the Plain where you intend to make your Line of Chords (whether upon a Ruler, a Paper, or Board) draw a handsome double Line and a single Line at a competent Distance from it, so as to leave Room between them for the Figures, as you see *Fig. 8.* and let these Lines be exactly the Length of the Line b c, from A to B, which done, and the Quadrant very carefully divided *Plate 12.* into 90 equal Parts, as before directed *Fig. 8.* ed, take a Pair of Compasses, and placing one Foot in the Point b, extend the other to the End of the first Degree, and keeping that Extent, place one Foot in the End of the double Line at A, and make a Mark where the other falls in the said Line; then again placing one Foot in b, as before, extend the other to the End of the second Degree, and set the same Extent on the Line A B from A towards B, and where

where that falls make another Mark. Proceed in the same Manner with the third, fourth, or fifth Degrees, &c. till you have thus transferred all the 90 Degrees of the Quadrant to the Line A B, (which if right done, will be unequal upon the Line A B, being largest at first, and lessening gradually towards the last) always observing at every Tenth Degree, as 10, 20, 30, &c. to carry the Division, through the single Line, and upon these Divisions place the Numbers 10, 20, 30, &c. for the more immediate Number of the Degrees, the intermediate Degrees between every 10, being to be numbred from the next less even ten, as the third small Division beyond 30 is 33, &c. and then is your Line of Chords finished.

It is always observed, that the Chord of 60 is equal to Radius, that is, when a right Line is truly divided by these Directions, the Extent from the Beginning of the Line at A to the 60 Degree, is just equal to g b the Semidiameter of the Circle, by which the said Line was divided; therefore in Practice, whenever you would draw a Circle, that you propose to divide by your Line of Chords, it must always be a Circle of the same Bigness of that, by which your Line of Chords was made, in order to which, whatsoever Line of Chords you intend to work with, take 60 Degrees of the Chord, (that is, the Extent from the Beginning of the Line to 60) and with that Extent, and one Foot where you intend to make your Center, sweep a Circle, or a half, or a quarter of a Circle, as you may have Occasion, and when you have any given Number of Degrees to set upon the Circle, from any given Point, extend your Compasses from the Beginning of the Line of Chords to the Degree proposed, and with that Extent,

Extent, and one Foot in the given Point, observe where the other Point falls upon the Circle, and make a Mark; for that is the Number of Degrees required.

EXAMPLE.

It is required to set 37 Degrees upon the Quadrant dc , from d towards c . Place one Foot of your Compasses in the Beginning of the Line of Chords at A , and extend the other to 37 Degrees; (*viz.* to seven small Divisions beyond the Number 30) then with that Extent applied to the Circle, one Foot in the given Point d , the other will reach to n , the Quantity of 37 deg. required.

To measure a given Arch of a Circle, is just the Reverse of this; for, take the given Arch, or the Distance between the two given Points in a Circle in your Compasses, and apply that Extent upon your Line of Chords, (always putting one Foot upon the Beginning of the Line) the moveable Foot falls upon the Degree required.

EXAMPLE.

It is required to measure the Arch dn in the Semicircle deb . Place one Foot of your Compasses in d , and the other in n , that Extent apply'd to the Chords, gives 37 deg. &c.

But no Line of Chords will measure any Circle, but those of the same Diameter with that from whom the Line is projected; therefore it may be proper to make or have Lines of several Radius's; but if you have not such Variety, that Deficiency may be in some Measure remedied thus:

To

To measure any Part of any Circle, (whether it be to a larger or lesser Radius than your Chords are made for, it matters not) take in your Compasses the Chord of 60 deg. from your Scale, and with one Foot in the Center of the Circle that is to be measured, draw a Circle which will be parallel to the Circle to be measured, but whether within or without, it is the same; but in this Case, we will suppose it falls without the Circle that you would measure. Lay a strait Ruler from the Center to the Point, from whence your Number of Degrees is to be set off, and observe where it cuts the Circle last drawn, and make a Mark, from which set the given Number of Degrees, and where the Degrees end, and from the Center, lay a Ruler, and observe where it cuts the first Circle; for between that Point, and the Point first proposed, is the Number of Degrees required to be set off.

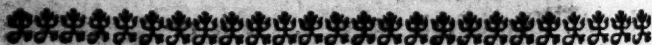
EXAMPLE.

In the Semicircle $x y z$, it is required to set off 37 deg. from x to. *Plate 12.* towards y , but having no Chord to *Fig. 8.* that Radius, take the common Chord, and with the Sweep of 60, draw the Circle $d c b$, upon which set 37 deg. from d to n , and laying a Ruler from the Center to n , it cuts the inner Circle in o , and the Arch $x o$ in the lesser Circle, is equal to $d n$ in the greater, viz. 37 deg. as required.

I speak of measuring or setting off promiscuously, one being the Reverse of the other, and further Repetitions would be needless.

BUT the best Way of dealing with Circles of different Radius's, is by a Sector, whereon you have the Chords commonly marked C , which
pro-

proceed from the Center to (near) the End of the same Side of both Legs, being exactly graduated alike; and in Order therewith to measure any Part of any Circle of what Diameter soever, First, Take in your Compasses the Radius or Semidiameter of the Circle, then open your Sector to that Wideness, that the Compasses (kept as they were) may reach from the Brass-point at 60 on one Leg of the Sector, to the Brass-pin or Point at 60 on the other Leg thereof; then if you would set off any Number of Degrees (suppose 45) from any Point in the *Periphery* of the said Circle, keeping your Sector at the same Opening, extend your Compasses from 45 on one Leg to 45 on the other, that Extent contains 45 Degrees of that Circle, and placing one Foot where the Leg in the other will find the Point where they end; and the same Method is to be used for Circles to any Radius or Arches containing any Number of Degrees.



SECTION XIII.

How to make a Dial that shall give the true Hour of the Day, without a Stile or Gnomon, only by the Shadow of one Part of it appearing upon another Part thereof.

THERE is one of this Sort of Dials near the South West Corner of Middle Moor-fields, and in some other Places in London; but for the making of them, you need have no Regard to the Latitude of the Place, for that is to be considered

dered in the placing, and not in the making of them; in order to which, prepare a Piece of Wood, Brass, or Iron, of Bigness at Pleasure, in the Form of a Cross, having one of the Four-ends longer than any of the *Plate 12.* other three, and let the Thickness of *Fig. 9.* it be about equal to the Length of one of the shortest Ends, as you see in the Figure a b c d e f g h i k l m, where b c and c d and l m are supposed equal, and f g equal to h i, is longer than any of them; then for finding the Hours, take a Piece of plain Plank, or Wainscot, as long as the Line f g, and as broad as the Length of the Line c d is intended to be in your Dial; such a Piece is exactly represented by Parallelogram, or long Square, f g h i, and which indeed may serve for the Purpose following.

TAKE the Extent f i, or h g, (which are equal) in your Compasses, and with one Foot in i, the very Intersection of the Side k e with the Side a h, and draw the Quadrant f n, which divide into 6 equal Parts for 6 Hours, because it is a Quarter of a Circle; and where these equal Divisions fall, make the Marks * * *, &c. A Ruler laid from the Center i, through the Marks * * *, &c. will cut the Line f g in the Points r x z, &c. then the Position of this Dial being to be with the End a b, to face the South, and the upper Part of the Dial to lie parallel to the Equinoctial, (not to the Horizon) the Sun at 12 a Clock will shine just along the Line a m or b c; and therefore place 12 at m and c, then it is plain, that from 12 to 3, the Shadow of the Corner a will pass along the Line m l; therefore take from your Projection the Distance f r, and

and place from 12 to 1. Take also $f x$, and place from m to 2, and the Distance $f z$ will be equal to $m l$; therefore, at 1 place 3, and at 3 in the Afternoon the Shadow of the Corner a , will go quite off the Side $l m$, but the Shadow e will be come upon the Line $f g$ as high as z ; therefore at z place 3, and at x place 4, and at r place 5, and then 6 must be in the Corner f , because at 6 the Sun will shine right along the Line $e f$; place 6 also at the Corner c , because the Sun at 6 shines right along the Line $c d$, and from 6 till 9 (if it be in a Latitude where the Sun continues up so late) the Shadow of the Corner at d is passing along the Line $c b$; therefore take in your Compasses the Distance $f r$, and set from 6 to 7. Take also $f x$, and set from 6 to 8, and the Distance $f z$ is equal to $c b$; therefore at the Corner b place 9, because the Shadow of the Corner d goes off the Line $b c$ at 9. Then for the Morning Hours, the Shadow of the Point l will enter upon the Line $a m$ at the Point a , just at 3 in the Morning; therefore draw Lines from 7 and 8 in the Line $b c$, which let be drawn parallel to $a b$, or $m c$, and having placed 3 at the Corner a , place 4 upon the End of the Line that comes from 8 and 5, upon the End of the Line that comes from 7, and then 6 will be in the Corner m , because at 6 the Sun shines just along the Line $l m$, and from 6 till 9 the Shadow of the Point k is passing along the Side $i h$; therefore having placed 6 in the Corner i , draw Lines from the Points $r x z$ parallel to $g h$, and at the other End of these Lines, viz. upon the Side $i h$, place the Hours of 7, 8 and 9, and when the Shadow of the Point k comes at 9, the Shadow of the Point b is at the Point d , and from 9 to 12, the Shadow of b passeth

passeth along the Line d c, and at 12, the Shadow of b is come to c; therefore take the Distances f r, f x, and f z, and set from e to 11 and 10, the Distance f z being just equal to c d, and then is your Dial finished; the Sun, as it goes off from one Part of it, comes on to another, so that the Time of the Day may be always found upon some Part or other of it, when the Sun shines.

THE Reason why these Dials require Thickness, as well as other Dimensions, is, because being placed parallel to the Equinoctial, the Sun shines upon the upper Face all the Summer, and at the Longest Day is elevated $23\frac{1}{2}$ deg. above the Plain of the Dial, and consequently the Shadow of a, will fall at Noon in the Line a m, but not in the Point m, but at an Angle of $23\frac{1}{2}$ deg. therewith, which must be accounted for in the Thickness of the Body of the Dial.

Note, It is not necessary that any of the Ends of the Dial should be longer than another, only for Ornament; but if you would make one of those Dials for any Place beyond the Artick or Antartick Circles, where the Sun is sometimes seen all the 24 Hours, it is necessary all the Ends should be alike, because then the Sun would come on to one Part as it goes off from another continually, which now it cannot; for the Sun coming up in the Morning, the Shadow of g would have quitted the Line f e at e, before the Shadow of l would come on to the Line a m at a; but if f g was cut off at z, and f z made equal to a m, or m l, &c. the Shadow of z would just quit e when the Shadow of l enters upon the Line a m at a.

THE

Mechanick Dialling.

The Sun's Place or Declination may be infered in these Dials as easily as in any; for if you take in your Compasses the Extent a m, and with one Foot in the Point or Corner a, and with the other sweep an Arch from the Corner at m downwards, and with that from a Chord to the same Radius, set off every 5 or 10 Deg. of Declination, or the Sun's Declination at his Entrance into each of the Twelve Signs, being set off upon the Circle, and Lines drawn through these Marks to the Corner under m, and from thence parallel to b m, and c d will give the Sun's Entrance into the 12 Signs by the Shadow of the upper Point a, in the Summer Season, while the Sun shines upon the upper Surface of the Dial; but in the Winter, the like Method must be used with the lower Part for the Southern Sign, the Declination increasing upwards, and decreasing downwards.

The Sun's Declination at his Entrance into the 12 Signs, is as followeth.

<i>North Declination.</i>			<i>South Declination.</i>		
	d.	m.		d.	m.
♈ Aries	0	0	♎ Libra	0	0
♉ Taurus	11	30	♏ Scorpio	11	30
♊ Gemini	20	12	♐ Sagittarius	20	12
♋ Cancer	23	30	♑ Capricornus	23	30
♌ Leo	20	12	♒ Aquarius	20	12
♍ Virgo	11	30	♓ Pisces	11	30

In making these Dials, there is no Regard to be had to the Latitude of the Place; that being to be considered in placing them, which must be done so, that the upper Face of the Dial may be just parallel

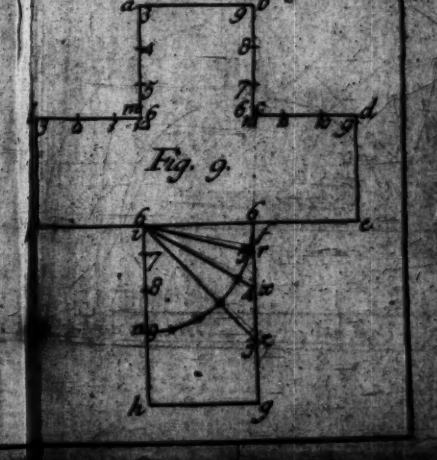
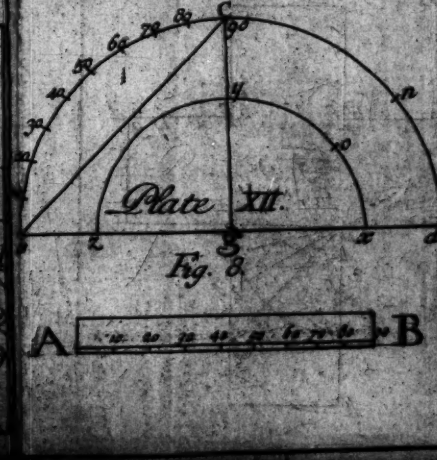
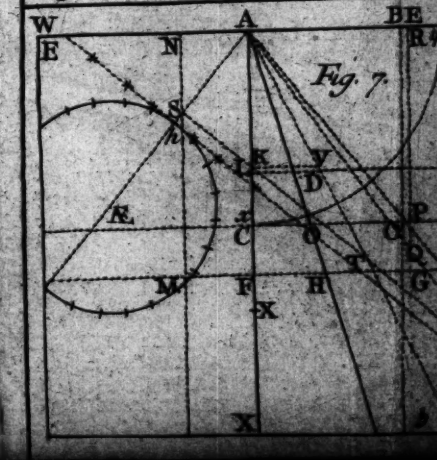
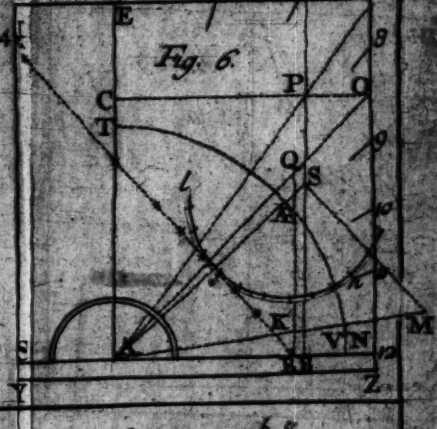
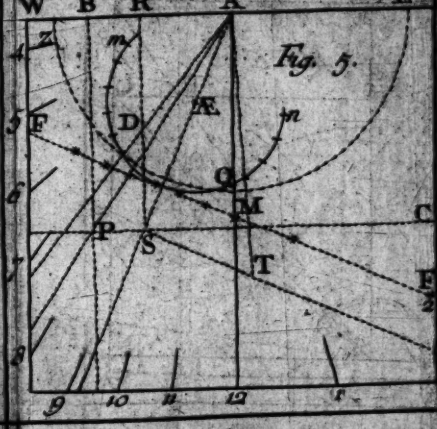
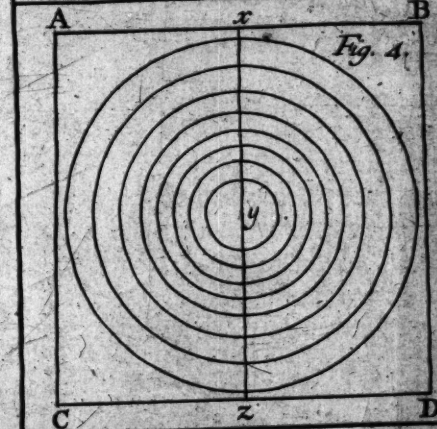
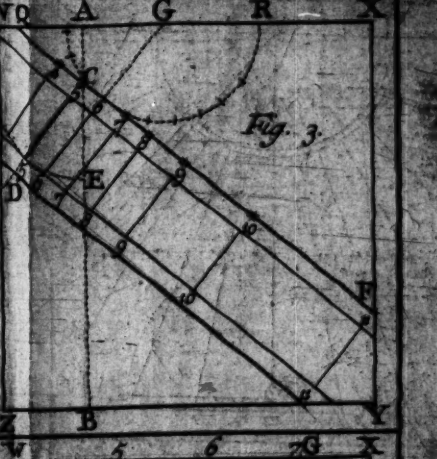
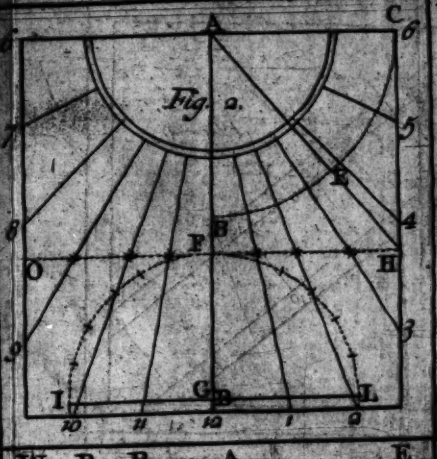
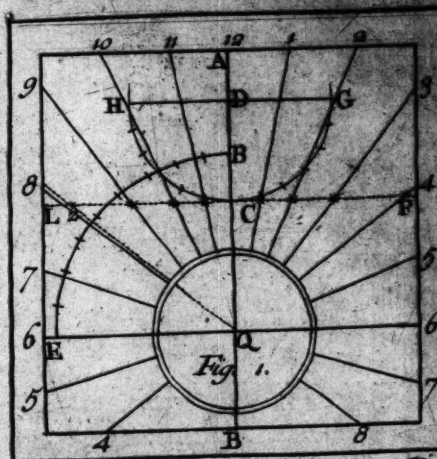


Plate XII.

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parallel to the Equator, the Line a m and b c, pointing at the South Part thereof; in Order to which, having found the Meridian of the Place, set the Dial exactly North and South, and lay a strait Ruler along the Middle of the Dial, from h g to a b, letting it hang over at the End a b; then on the under side of that Part of the Ruler that hangs over, fix a Gunter's Quadrant with one of its strait Sides to the Ruler, and the Center towards the End of the Ruler; which done, elevate the End a b of your Dial by little and little, till the Plummet (having free Liberty to play) falls upon the Complement of the Latitude of the Place; or, (which is the same) till the Plain of the Dial make an Angle with the Horizon equal to the aforesaid Complement of Latitude; then is your Dial fit for Observation, there being always some Side of it, upon which the Hour of the Day may be seen, if the Sun shines.



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CHAP



C H A P. XII.

Of Painting of DIALS.

SECTION I.

1. *How to prepare your Oyl for laying on the Colour upon Dials.*

TAKE one Gallon of Linseed Oyl, and set it upon a Charcoal Fire, and when it is about to boil, put into it two Pound of Red-lead, and let it boil together for about an Hour; but the best Way to know, when it is boiled enough, is to take a little of it out, and let it cool, and then if it roaps like thin Tar, it is enough. This done, put a lighted Paper to it, and set it on Fire, to consume the greasy Part of it, which will be done in a Minute or two, or more or less, according to the Quantity of your Oyl; and when it has burnt long enough, clap a Cloth, or any other thing close over it, and extinguish the Fire; after which let it cool and settle, then decant the clear Oyl from the Dregs, and keep it in a Bladder for use.

THIS is called drying Oyl, and with this the several Colours are to be ground, in order to paint, so as to endure the Weather, (being first dry, before it be exposed) the several Colours we shall describe hereafter.

2. *How*

2. *How to make Gold Size, with which to lay on Leaf Gold.*

TAKE yellow Oker, and grind it with Water on a Stone, with a Muller, till it be very fine, and then lay it to dry, and grind it with the aforementioned drying Oyl, as you would grind other Colours, observing to put so much of each that it may be of competent Stiffness to work well, and of such a Body, that it may settle itself smooth when laid on, but not so thin as to run; and take Care to grind it very fine, and it will add the greater Beauty to your Gold that is to be laid on with it.

SECTION II.

Of Colours used in painting Sun Dials.

THE Colours generally used in painting Sun-Dials, are,

1. FOR *White*, Ceruse and White-lead.
2. FOR *Black*, Lamp-black, Ivory-black, Charcoal and Seacoal-black.
3. FOR *Red*, Red-lead, Vermilion, and Cinabar Lake.
4. FOR *Green*, Verdigrease.
5. FOR *Blew*, Indico, blue Bice, blue Verditer, and Smalt.
6. FOR *Yellow*, Yellow Oker and yellow Pink.
7. FOR *Brown*, Spanish Brown.

Of these Colours you may compound Variety of other Colours, as,

1. A little Lamp-black with White, makes an Ash-colour.

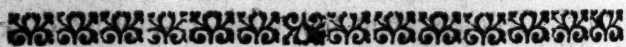
2. CINNABAR Lake is a rich Crimson Colour, but mixt with Bice, it makes a fine Purple, according to the Proportion of Mixture; but mixt with White, it makes a fine Carnation.

2. BLEW Bice mixed with yellow Pink, makes a Green; with Lake a Purple; and with White a light Blue. And note, that any Blue and Yellow mixed, make a Green of some Sort or other.

4. INDICO mixed with White, makes a Lead Colour.

VERDIGREASE mixt with Yellow Pink, makes a lively Grass-green.

By this Means may several other Colours be compounded, and made lighter or darker, at Pleasure, as a little Practice will make evident.



SECTION III.

How to prepare the Colours for Painting Sun-dials.

BEFORE you proceed to the painting of Sun-dials in their several Colours, it is first necessary that they be primed; that is, painted two or three Times over with Oyl and Colour, prepared for that Purpose, to fill up the Cavities, which may (after plaining) remain in the Wood, and to make it perfectly plain, and the more capable

ble to receive and retain other Colours; and of all priming, *Spanish Brown* is reckoned to be the chief; for, not to mention its Cheapness, it dries kindly, and gives the Oyl sufficient Time to penetrate into the Wood, and consequently also resists the Weather, and also freely receives all other Colours which are laid upon it. It is of itself of a Horse-flesh-colour, and (besides its Usefulness in priming) it is a natural Shadow for Vermillion, and may be made lighter or darker, according to the greater or less Quantity of White mixt with it; but in priming, it requires not any Mixture, but only the Oyl it self.

In preparing the *Spanish Brown* for priming, grind it very well with the afore-mentioned drying Oyl, and make it for the first priming, somewhat thinner than you would do it for painting, that it may more easily penetrate into the Wood; which being dry, do it over again with the same Mixture, only mix it a little thicker; and letting that dry, do it a third Time, mixing your Colour thicker every Time. And take Care in the priming not only to rub the Brush with the Priming upon the Dial, but also bob it against it, that the Priming may be sure to pierce into all the Cavities or Pores of the Wood. This done, and your Dial dry, the third Time it is ready for laying on the Colours, viz. painting the Hour-lines, or what Ornament or Furniture you think fit to have upon it.

If you are but for making a common Sun Dial, these four Sorts of Colours will be sufficient.

1. *Spanish Brown*, which prepare, and therewith prime your Dial, as before directed.

2. *White-lead*, well ground in Oyl, with which after the Priming is thoroughly dry, go over it three or four Times, letting it dry between every Time; which not only makes a beautiful white Ground, but fortifies it yet more against the Fury of the Weather.

3. *Lamp-black*, for drawing the Hour-lines and Figure.

4. *Vermillion*, for drawing the Parallels of Declination, or what other Furniture you think fit to put upon it.

THE *Spanish Brown*, *Lamp-black*, and *Vermillion*, are all to be ground in the drying Oyl, described at the Beginning of this Chapter; and for the *White-lead*, it is to be used in the same Manner, only in making drying Oyl for *White-lead*, instead of *Red-lead*, use *Litharge of Gold*, and proceed as before.

BUT if you would have your Dial more rich, you must first consider, what Colours you resolve to have your Lines, Figures, &c. to be; and upon what Ground your determined Colours will appear most beautiful, as,

1. *GOLD* appears best upon a blue Ground, and indifferently upon a Red.

2. *BLUE* and *Green* appear best upon *Yellow* and *White*

3. *RED* sets off with *Yellow*, *White*, *Blue*, or *Green*.

4. *YELLOW* sets off with *Black*, *Blue*, and *Red*.

BESIDES the Directions given already for preparing and laying on common Colours, it will be necessary to speak of the laying on the more rich and beautiful Colours; and first,

How to lay on Leaf Gold, or to make any Lines, Figures, &c. of Leaf Gold upon your Dial.

DRAW your Lines, Figures, or Letters, (or what you think fit to have in Gold) with Gold-size; (of which before) which let dry so, that when you touch it with your Finger, it will stick, but not come off; then cut your Leaf Gold, as near as you can, into the Form you would have it, whether of Figures, Letters, Lines, &c. (taking Care to cut it rather too large, than too little) and with a flat Stick lin'd with Cloth, take up your Gold (so cut) and put it upon the Size, and the Gold will leave your lin'd Stick, and cleave to the Size; then press it down with Cotton, or a Hare's Foot, and take care that you make the Figures, Lines or Letters, in the Gold-size, and that you cut the Gold large enough to cover the Figures so made in the Size; and when it is thoroughly dry, brush off all the loose Gold, and the Painting will remain beautiful, and be able to endure the Weather.

How to lay on Smalt, to make a fine Blue.

WHEN you have laid on what you think fit in Leaf Gold; take White-lead, mix it pretty stiff with drying Oyl, and with a Pencil lay that on, where you intend your Blue shall be, and then put your Smalt in a fine Searce, and sift it on to the Dial, and with a Piece of Cotton, dab it down upon the White before laid on, and when it is

thoroughly dry, wipe off all the loose Colour with a Feather, and blow off the Dust with a pair of Bellows, which will easily blow off, except what fell upon the White before laid on to retain the Blue, which will be a very beautiful Blue.

OBSERVE as a general Rule, that Priming is to be mixt or temper'd thin, but Colours for Lines or Figures to endure the Weather, must be temper'd thicker, the better to resist the Fury of stormy, or moist Weather.



SECTION IV.

Of the Nature and Colour of some of the principal Ingredients used in painting of Sun-Dials.

1. **CERUS** and *White-lead*, are the only Colours to be used in painting in Oyl, and besides their Usefulness in painting of Dials, Paint made up with them and Oyl, is frequently made use of in painting Posts, Palisadoes, Gates, Doors, Windows, Wainscoting, &c. and answers the End of Painting, both as to Beauty and Preservation; for they dry well, and strongly resist the Weather. But if you would have them to dry yet more speedily, you may in the Tempering put in a little Oyl of Turpentine, if it be within Doors, but without Doors it is better without, because that does not so well resist the Weather.

2. *Lamp*

2. *Lamp-black* is a good Black, if it be first burnt, then ground, and lastly tempered with Oyl.

3. *Charcoal* is a Black that will serve for ordinary Uses; it dries well, but great Care must be taken that it be well ground.

4. *Spanish Brown*, the best is a deep bright Colour, and free from Stones, and being very well ground, is the best for priming: It is of a Horse-flesh Colour, and a proper Shadow for Vermilion.

5. *Red-lead* is a great Dryer and Binder; for which Reason, it is made use of in the drying Oyl; it resists the Weather as well as any Colour whatsoever.

6. *Vermilion* is a rich Colour, and of a good Body, but care must be taken that it be finely ground, even as soft as Oyl, and then it will work extraordinary well: It is best to buy it in the Stone, lest you meet with some that has been adulterated with Red-lead, or the like; it is a perfect Scarlet of it self, and may be altered to several Varieties, by mixing with other Colours.

7. *Cinnabar-lake* is a rich Crimson Colour, and must be very fine ground.

8. *Smalt* is a very fine Blue, and it is best to be strewed on, as before taught; for if you work it in Oyl, (though you wash it, and mix it with White-lead) yet it will turn black in Time: If you buy it to work in Oyl, the finest is best, which is call'd *Oyl-Smalt*.

9. *Blue Bice* is a pale Colour, and works well though a little sandy.

10. *Blue Verditer* is not so good a Blue as *Bice* and *Smalt*, though it may serve in Dial-painting,

where they are wanting ; it is a little sandy, and apt to fade and turn greenish.

11. *Indico* is a very dark Blue, and commonly lightened with White, when us'd in Painting, except in Shadowing ; it grinds fine, and is very proper for the last Colour of Posts, Palisadoes, Doors Windows, &c. for it resists the Weather, and preserves the Wood.

12. *Blue Balls* are almost like Indico, but not so good a Colour, nor will it endure so long.

13. *Umber* is a Hair Colour, it must be very fine ground, which to effect, requires a great deal of Labour ; it dries and binds exceedingly, and is therefore also very proper for painting without Doors, as Doors, Palisadoes, &c. if calcin'd in a *Crucible*, it is a natural Shadow for Gold, and some other Colours.

14. *Verdigrease* is a perfect Willow-green, but may be altered at Discretion, with Yellows, &c. but being very foul, it must be mended or cleansed ; which may be thus done : Grind it fine, and put to it eight Times its Weight of Spirit of Vinegar ; digest till the Vinegar is tinged very green, then decant the Colour ; cast away the Faces, and evaporate the Vinegar in a Brass Vefica ; so have you a very good *Verdigrease* at the Bottom, much more fine and valuable, than before it was cleansed. It dries very speedily.

15. *Yellow Oker*, the *English*, the Colour of a fresh Wheat Straw ; the foreign is somewhat more deep a Colour ; it is much used in common Painting, being ground very fine.

16. *Yellow Pink* is a greenish Yellow ; it grinds well, and is good to mix with other Colours, to make a Green.

Of these Colours, some require washing, as *Red Lead, Blue Bice, Smalt and Verditer*; which is thus performed:

PUT the Colour into a glazed Vessel, and put thereto plenty of clear Water, wash it well, and (after a while) decant the Water. Repeat this Work six or seven Times; at last (the Water being but just troubled) put it into another glazed Vessel, leaving the Dregs at the Bottom; then put some more Water into this second Vessel, and wash it as before, till the Water after settling be clear, and the Colour remain fine at the Bottom.

Note, Before you take the Colour out of the Vessel, spread it about the Sides of the Vessel very thin; and when it is dry, it will part of it fall down to the Bottom, which keep by it self; but that which sticks to the Sides of the Vessel is the best, and is as fine as any Flower, that strike off with a Feather, and keep it for Use.

THE Colours that require washing being thus prepared, (or if they are those that do not require washing, they are done without) your next Work is to grind them, which is done thus:

TAKE a Spoonful or two of the Colour you intend to grind, and put to it a little Linseed-Oyl, (but be careful you put in too little rather than too much); mix them together, and upon your Stone with a Muller, grind them well, adding Oyl by Degrees, as you see it requires it, to make it like an Oyntment, (always observing, that it grinds much better when it is thick, than when it is so thin as to run about the Stone) every now and then scrape it up together with a thin Knife, or Lantern Horn, to keep it at or near the middle of the Stone, and so continue to work, till you have ground as much as you have Occasion

for; which done, clean your Stone, by grinding Sand and Water upon it, and then wash and dry it, and the Muller; and when you go to make use of it, mix it with drying Oyl, till it be so thin as to run freely from the Pencil, yet so thick, that the Ground may not appear through it, or to run when it is laid on, and then it will be the more beautiful Colour, and better endure the Weather.



SECTION V.

How to make some Original Colours, &c.

1. To make White-Lead.

TAKE as many Plates of fine Lead as you please, and then put them into an earthen Pot, or Crucible, fill the Pot with White-wine Vinegar, and cover the Top of it close with Clay, bury it in a Cellar, or some moist Place, for seven or eight Weeks, and there will be White-lead upon the Plates, which wipe off, and keep for Use.

2. To make Verdigrease.

HANG Plates of Copper over the Fumes of Aqua-fortis, or Spirit of Nitre; or dip the Plates in the same, or in Vinegar, and the Rust or Scurf that is by that Means bred upon the Plates, is Verdigrease.

3. To

3. To make Ultramarine.

TAKE *Lapis Lazuli*, the deepest coloured you can get, having few Veins of Gold in it, cover it close up in a Crucible, and heat it red hot, and then quench it with Urine, Vinegar, or Water, in an Earthen Pot well leaded; dry it well, then with a pair of Pincers pull off the hard, white or grey Parts of it, then grind the rest very fine with Honied Water, and dry it, and keep it for Use.

Note, The Honied Water is made by boiling a Quart of Water with two Spoonfuls of Honey.

4. How to make the best Glue, for gluing the Joints of Boards for Dials, or the like.

TAKE Milk that hath stood so long, and been scum'd so often, that no more Cream will arise; and when scum'd very clean, boil it a little in a leaden Pot, and if any Cream yet arise, be sure to take it clean off; then put into the Milk a sufficient Quantity of Glue cut in small Bits, which will soon melt: Boil it to a good Body, but not too thick nor too thin; then take it from the Fire, and keep it for Use.

Note, You must take Care, that in boyling it you do not burn it to the Sides of the Pot, for that takes away much of the Strength of the Glue; but if it be made with due Care, it binds beyond any other Glue, and is better able to resist the Weather; and therefore, the fittest for glueing Boards for Sun-Dials, or the like.

5. *How to make an exceeding strong Cement or Plaster, with which to form any Dial-plain upon the Side of a House or Wall, and to endure the Weather, not inferior to Stone.*

TAKE Lime and Sand, and temper it with Linseed-Oyl to the Consistency of Mortar, or common Plaster, and spread it upon the Wall to a competent Thickness, it will become as hard as a Stone, and last many Ages; and upon this you may describe a Dial, and put on the Lines, Figures and Furniture, as before directed.

Note. If you are in the Country, remote from any Opportunity of getting Linseed-Oyl, you may make it with scum'd Milk, which will be very superior to Plaster made with Lime, Hair, and Water.

HAVING proceeded thus far in Colours for Painting to endure the Weather, it may not be improper to add something of transparent Colours for the Colouring of Maps, or any Draughts upon Paper or Vellum; of which, in Order.

First, A Yellow.

THE finest that you have Occasion to use, will be your *French yellow Berries*, which steep'd in a Gallipot of Water, with a very little Allum, about 12 Hours, makes a very beautiful Colour.

Secondly, A Red.

TAKE a Quantity of Brazil, about four Ounces, and boil in a Pint of Grounds of Ale, adding about a Quarter of a Pint of Vinegar, a small Quantity of Gum-Arabick, and about an Ounce of

Of Painting Sun-Dials.

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of Allum; let them boil very well, and strain the Colour through a fine Linnen Cloth.

Thirdly, A Sea Green.

TAKE a Quantity of Verdigrease, about four Ounces, boil it in a Pint and a half of Water, first putting about half an Ounce of Argul to it, let it boil till the Colour stains pretty deep.

Fourthly, A Grass Green.

Is compounded of the Yellow of yellow Berries, and the Sea-Green mixt according to Discretion.

THE *Fifth*, which is brown, commonly used for Roads, Barks of Trees, &c. is burnt Umber, which you must grind very fine, with some Gum-water.

Gum-water is only Gum-Arabick steep'd in Water, till dissolv'd.



A TABLE of the three Requisites in Dialling,
for Latitude 51 deg. 30 min.

Declination.	Substile's Distance Meridian.		Stile's Height.		Inclination of Meridian.		Declination.	Substile's Distance Meridian.		Stile's Height.		Inclination of Meridian.	
	d.	m.	d.	m.	d.	m.		d.	m.	d.	m.	d.	m.
1	00	48	38	29	01	17	22	16	36	35	16	27	18
2	01	36	38	28	02	33	23	17	16	34	57	28	29
3	02	23	38	26	03	49	24	17	56	34	39	29	38
4	03	11	38	23	05	07	25	18	37	34	21	30	47
5	03	58	38	20	06	23	26	19	12	34	01	31	56
6	04	45	38	15	07	39	27	19	50	33	42	33	04
7	05	32	38	10	08	55	28	20	22	33	20	34	12
8	06	19	38	04	10	11	29	21	05	32	59	35	19
9	07	05	37	57	11	27	30	21	40	32	37	36	25
10	07	52	37	49	12	42	31	22	15	32	15	37	31
11	08	38	37	40	13	57	32	22	50	31	52	38	36
12	09	23	37	30	15	10	33	23	25	31	27	39	41
13	10	08	37	21	16	26	34	23	59	31	04	40	46
14	10	54	37	10	17	40	35	24	31	30	40	41	49
15	11	38	36	58	18	54	36	25	04	30	14	42	52
16	12	22	36	43	20	07	37	25	35	29	48	43	55
17	13	05	36	32	21	20	38	26	04	29	22	44	58
18	13	42	36	18	22	33	39	26	35	28	56	45	59
19	14	31	36	03	23	45	40	27	03	28	29	47	00
20	15	13	35	48	24	57	41	27	33	28	01	48	00
21	15	54	35	31	26	08	42	28	01	27	33	49	00

A TABLE of the three Requisites in Dialling,
for Latitude 51 deg. 30 min.

Declination.	Substile's Distance Meridian.		Stile's Height.		Inclination of Meridian.	
	d.	m.	d.	m.	d.	m.
43	28	29	27	5	50	00
44	28	55	26	36	50	59
45	29	21	26	07	51	57
46	29	46	25	37	52	55
47	30	11	25	07	53	53
48	30	35	24	38	55	50
49	30	58	24	06	55	46
50	31	21	23	35	56	42
51	31	45	23	04	57	38
52	32	05	22	32	58	33
53	32	26	22	00	59	28
54	32	46	21	28	60	23
55	33	06	20	55	61	17
56	33	24	20	22	62	10
57	33	42	19	49	63	04
58	34	00	19	16	63	57
59	34	13	18	42	64	49
60	34	33	18	06	65	41
61	34	47	17	34	66	33
62	35	05	17	00	67	24
63	35	18	16	25	68	16
64	35	34	15	50	69	07
65	35	43	15	15	69	57
66	36	00	14	40	70	47
67	36	13	14	05	71	38
68	36	25	13	29	72	27
69	35	36	12	53	73	16
70	36	40	12	11	74	06
71	36	55	11	41	74	55
72	37	06	11	06	75	44
73	37	15	10	29	76	33
74	37	24	09	53	77	21
75	37	32	09	16	78	09
76	37	40	08	40	78	57
77	37	47	08	03	79	46
78	37	57	07	27	80	33
79	37	59	06	49	81	21
80	38	04	06	12	82	00
81	38	09	05	35	82	36
82	38	14	04	58	83	43
83	38	17	04	20	84	31
84	38	21	03	44	85	18
85	38	23	03	06	86	05
86	38	26	02	28	86	52
87	38	28	01	52	87	39
88	38	29	01	15	88	26
89	38	29	00	37	89	13
90	38	30	00	00	90	00

A TABLE of Meridional Angles.

A TABLE of Meridional Angles.									
Hor. Dial. Lat.	xi.	i. x.	ii. ix.	iii. viii.	iv. vii.	v.	vi.	South Dial Lat.	
	d.	m. d.	m. d.	m. d.	m. d.	m. d.	m.		
0	0	00	00	00	00	00	00	90	
1	0	160	341	01	443	44	90	89	
2	0	321	92	03	277	25	90	88	
3	0	481	443	05	1111	3	90	87	
4	1	52	194	06	5414	36	90	86	
5	1	202	524	588	3518	190	0	85	
6	1	363	275	5810	1621	1990	00	84	
7	1	524	36	5711	5524	2790	00	83	
8	2	84	371	5513	3327	2390	00	82	
9	2	235	98	5415	1030	1790	00	81	
10	2	405	439	5116	4432	5590	00	80	
11	2	556	1710	4818	1735	2790	00	79	
12	3	116	5111	4519	4037	4990	00	78	
13	3	277	2412	4121	1740	150	00	77	
14	3	437	5713	3622	4442	490	00	76	
15	3	588	3014	3124	044	090	00	75	
16	4	139	215	2525	3145	4990	00	74	
17	4	299	3516	2626	5247	2690	00	73	
18	4	4410	817	1028	949	490	00	72	
19	4	5910	3918	229	2550	3390	00	71	
20	5	1411	1018	5330	3951	5590	00	70	
21	5	2911	4119	4431	5053	990	00	69	
22	5	4412	1220	3232	5854	2190	00	68	
23	5	5912	4321	2034	555	3090	00	67	
24	6	1313	1322	835	1056	3790	00	66	
25	6	2813	4322	5536	1257	3490	00	65	
26	6	4214	1223	4037	1358	3490	00	64	

Mechanick Dialling.

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A TABLE of Meridional Angles.																					South Dial La.
Hor. Dial La.	xi.		i. x.		ii		ix.		iii.		viii.		iv.		vii.		v.		vi.		
	d. m.		d. m.		d. m.		d. m.		d. m.		d. m.		d. m.		d. m.		d. m.		d. m.		
27	6	56	14	41	24	25	38	11	59	27	90	00	63								
28	7	10	13	10	25	9	39	7	60	17	90	00	62								
29	7	24	15	40	25	52	40	2	61	4	90	00	61								
30	7	38	16	6	26	33	40	54	61	49	90	00	60								
31	7	50	16	34	27	15	41	44	62	30	90	00	59								
32	8	5	17	1	27	55	42	30	63	11	90	00	58								
33	8	19	17	27	28	34	43	20	63	49	90	00	57								
34	8	31	17	54	29	13	44	5	64	24	90	00	56								
35	8	44	18	20	29	50	44	49	64	58	90	00	55								
36	8	57	18	49	30	27	45	31	65	30	90	00	54								
37	9	10	19	9	31	2	46	12	66	10	90	00	53								
38	9	22	19	34	31	37	46	50	66	29	90	00	52								
39	9	34	19	58	32	11	47	28	66	56	90	00	51								
40	9	45	20	21	32	44	48	7	67	21	90	00	50								
41	9	57	20	44	33	16	48	39	67	47	90	00	49								
42	10	10	21	7	33	46	49	12	68	11	90	00	48								
43	10	22	21	29	34	18	49	44	68	33	90	00	47								
44	10	32	21	51	34	47	50	10	68	54	90	00	46								
45	10	44	22	12	35	17	50	46	69	15	90	00	45								
46	10	54	22	33	35	44	51	15	69	35	90	00	44								
47	11	5	22	53	36	11	51	41	69	53	90	00	43								
48	11	17	23	13	36	37	52	9	70	11	90	00	42								
49	11	25	23	33	37	3	52	35	70	28	90	00	41								
50	11	35	23	52	37	28	53	00	70	43	90	00	40								
51	11	45	24	9	37	52	53	24	70	59	90	00	39								
52	11	55	24	27	38	15	53	46	71	13	90	00	38								
53	12	5	24	43	38	37	54	12	71	28	90	00	37								
54	12	13	25	2	38	58	54	29	71	41	90	00	36								
55	12	22	25	18	39	19	54	49	71	54	90	00	35								
56	12	32	25	34	39	40	55	9	72	5	90	00	34								
57	12	40	25	50	39	50	55	28	72	17	90	00	33								
58	12	48	26	5	40	01	55	45	72	28	90	00	32								

A TABLE of Meridional Angles.																				Vert. Dial. Lat.
xi.		i. x.		ii.		ix.		iii.		viii.		iv.		vii.		v.		vi.		
d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	
59	12	56	26	20	40	36	56	3	72	38	90	00	31							
60	13	4	26	34	40	54	56	19	72	48	90	00	30							
61	13	11	26	47	41	10	56	34	72	58	90	00	29							
62	13	19	27	1	41	21	56	49	73	7	90	00	28							
63	13	26	27	13	41	42	57	3	73	15	90	00	27							
64	13	32	27	25	41	57	57	17	73	24	90	00	26							
65	13	36	27	37	42	15	57	30	73	32	90	00	25							
66	13	46	27	49	42	25	57	43	73	39	90	00	24							
67	13	51	27	59	42	38	57	54	73	46	90	00	23							
68	13	57	27	9	42	50	58	5	73	53	90	00	22							
69	14	3	28	19	43	2	58	16	73	59	90	00	21							
70	14	7	28	29	43	13	58	26	74	5	90	00	20							
71	14	13	28	37	43	18	58	35	74	11	90	00	19							
72	14	18	28	46	43	24	58	44	74	16	90	00	18							
73	14	22	28	54	43	36	58	52	74	20	90	00	17							
74	14	27	29	2	43	52	59	00	74	25	90	00	16							
75	14	30	29	7	44	00	59	7	74	30	90	00	15							
76	14	33	29	15	44	8	59	15	74	34	90	00	14							
77	14	37	29	21	44	14	59	22	74	37	90	00	13							
78	14	41	29	27	44	22	59	27	74	40	90	00	12							
79	14	44	29	32	44	28	59	32	74	44	90	00	11							
80	14	47	29	37	44	34	59	37	74	47	90	00	10							
81	14	49	29	41	44	37	59	40	74	49	90	00	9							
82	14	51	29	45	44	40	59	44	74	51	90	00	8							
83	14	53	29	49	44	44	59	47	74	53	90	00	7							
84	14	55	29	52	44	48	59	51	74	55	90	00	6							
85	14	56	29	54	44	53	59	54	74	57	90	00	5							
8	14	57	29	55	44	55	59	55	74	58	90	00	4							
87	14	58	29	56	44	56	59	56	74	58	90	00	3							
88	14	59	29	57	44	57	59	58	74	59	90	00	2							
89	14	59	29	58	44	58	59	59	74	59	90	00	1							
90	15	00	30	00	45	00	60	00	75	00	90	00	0							



The USE of the
T A B L E S.

THE Design of the first Table, (Entituled *A Table of the Three Requisites in Dialling, for Latitude 51 Degrees, 30 Minutes*) is to save the Trouble of Calculation, according to the Directions given elsewhere in this Book, and is adjusted to Latitude 51 deg. 30 min. and to all Declinations in that Latitude. Its Use is, if it is required to make a Dial for Latitude 51 deg. 30 min. to decline any Number of Degrees from the Meridian, seek the Declination in the first Column, entituled, (*Declination*) and against it in the second Column, you have the Substile's Distance from the Meridian: In the Third you have the Height of the Stile, or the Angle that the Stile makes with the Plain; and in the fourth Column, you have the Inclination of Meridians, or what is by some called the Plain's Difference of Longitude ready calculated.

EXAMPLE.

It is required to make a Dial for Latitude 51 deg. 30 min. to decline from the Meridian 36 deg. (it is no Matter in this Case, whether the Declination be East or West, the Requisites being the same in Quantity in both, only upon different Positions,) I look in the first Column, entitled, (*Declination*) for 36 Degrees the Declination proposed, and I find against it in the second Column 25 deg. 4 min. for the Substile's Distance from the Meridian, or the Angle, which the Substile makes with the Meridian, or perpendicular Line of the Plain. In the third Column I find 30 deg. 14 min. for the Height of the Stile, or the Angle that the Stile makes with the Plain of the Dial. In the third against 36 deg. you find 42 deg. 52 min. for the Inclination of Meridians, or the Plain's Difference of Longitude, which being all found by Inspection in the Table, you may proceed to make your Dial as elsewhere directed in this Book, and that without any more Trouble of Calculation.

AND by the same Rule, if you would make a Dial for the aforesaid Latitude of 51 deg. 30 min. to decline from the Meridian 86 deg. you find in the Table the Substile's Distance from the Meridian is 38 deg. 26 min. the Stile's Height is 2 deg. 28 min. and the Inclination of Meridians is 86 deg. 52 min. But in this Case, the Height of the Stile is so small, that it is best to make the Dial without a Center; of which before.

The Use of the Tables.

THE second Table, entituled (*A Table of Meridional Angles*) contains eight Columns, of which the first contains the Latitude proposed for a Horizontal Dial; and the last is the Complement thereof, which is also the Latitude for direct South Dials; it is of Use in both sorts of Dials.

E X A M P L E.

I would make a Horizontal Dial for Latitude 54 Degrees. I look in the first Column of the Table under (*an Horizontal Dial Latitude*) for 54 Degrees, and against it in the second Column, I find 12 Degrees 13 Minutes, and over the Top of that Column xi. i. which shews, that the Hour-lines of 11 and 1 make an Angle with the Meridian of 12 Degrees, 13 Minutes. In the third Column, you have 25 Degrees, 2 Minutes, and over that Column is x. ii. viz. the Hour-lines of 10 and 2, make an Angle with the Meridian of 25 Degrees, 2 Minutes, and consequently, the Hour-lines of 9 and 3, make Angles with the Meridian of 38 Degrees 58 Minutes. The Hour-lines of 8 and 4 make Angles of 54 29, the Hour-lines of 7 and 5, make Angles of 71 and 74, the Hour-line of 6 making always right Angles with the Meridian.

E X A M P L E.

If you would make a direct South Dial, the Rule is the same, only you are to find the given Latitude on the right Hand, or Column of the Table, and proceed as before; as suppose you would make a South Dial for Latitude 40 deg.

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you

The Use of the Tables.

Look in the Table against 40, in the last Column, that the Hour-lines of 11 and 1, make Angles with the Meridian of 11 Degrees, 35 Minutes; the Hour-lines of 10 and 2 make Angles of 23 Degrees 52 Minutes; and so in the rest, as in the Table, the Hours on a South Dial being to be numbred contrary to those of a Horizontal Dial, as hath been sufficiently taught in the former Part of this Book.



F I N I S